# FA-01a WATER QUALITY MONITORING STUDY REPORT

# SKAGIT RIVER HYDROELECTRIC PROJECT FERC NO. 553

**Seattle City Light**

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**March 2023**
**Updated Study Report**

**TABLE OF CONTENTS**

## List of Figures

## List of Tables

## List of Attachments

## List of Acronyms and Abbreviations

°C ...............................degrees Celsius
ALK ...........................alkalinity
B-IBI ..........................benthic index of biotic integrity
BMI ............................benthic macroinvertebrate
$CaCO_3$/L.....................calcium carbonate per liter
CBOD ........................carbonaceous biochemical oxygen demand
cfs ...............................cubic feet per second
CFU ............................colony-forming units
Chl *a* ...........................Chlorophyll *a*
City Light ...................Seattle City Light
COC ...........................chain-of-custody
CoSD ..........................City of Seattle datum
cm...............................centimeter
CWA ..........................Clean Water Act
DIN ............................dissolved inorganic nitrogen
DO ..............................dissolved oxygen
DOC ...........................dissolved organic carbon
*E. coli* .........................*Escherichia coli*
Ecology ......................Washington Department of Ecology
EPA ............................Environmental Protection Agency
EPT ............................Ephemeroptera, Plecoptera, and Trichoptera
FC...............................fecal coliform
FERC..........................Federal Energy Regulatory Commission
ft ................................foot
g……………………grams
IQR............................interquartile range
ISR ............................Initial Study Report
lbs ..............................pounds
LP ..............................licensing participant
m ................................meter
MDL..........................method detection limit

MDN ..........................marine derived nutrients
mg/L..........................milligram per liter
mL.............................milliliter
mm ............................millimeter
mmHg ........................millimeter of mercury
µ ................................micron
µS/cm.........................microsiemens per centimeter
MW ............................megawatt
NAVD 88...................North American Vertical Datum of 1988
NCCN ........................North Coast and Cascades Inventory & Monitoring Network
ND..............................non-detectable
$NH_4$ ............................ammonium
NIST...........................National Institute of Standards and Technology
$NO_x$ ............................Nitrate
NPS ............................National Park Service
NTU ...........................nephelometric turbidity unit
NWS...........................National Weather Service
NYSDEC....................New York State Department of Environmental Conservation
$org/m^3$ .....................organisms per cubic meter
PAD............................Pre-Application Document
$PO_4^{-3}$ ...........................orthophosphate
POC............................Particulate organic carbon
PRM ...........................Project River Mile
Project ........................Skagit River Hydroelectric Project
PQL............................practical quantitation limit
QA/QC .......................quality assurance/quality control
QAPP .........................Quality Assurance Program Plan
RSD............................relative standard deviation
RSP ............................Revised Study Plan
SOP ............................Standard Operating Procedure
SPD ............................Study Plan Determination
SR...............................State Route
TDG ...........................total dissolved gas

TIC ............................total inorganic carbon

TKN ...........................total Kjeldahl nitrogen

TP...............................total phosphorus

TOC............................total organic carbon

TSS.............................total suspended solids

USFWS ......................U.S. Fish and Wildlife Service

USGS .........................U.S. Geological Survey

USR............................Updated Study Report

WAC ..........................Washington Administrative Code

WDFW.......................Washington Department of Fish and Wildlife

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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 (FA-01b WQ Model Development Study), which is addressed in a companion report (City Light 2023a). 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 (USFWS), Washington State Department of Ecology [Ecology], and Washington Department of Fish and Wildlife [WDFW]). 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 FERC's modifications from the SPD and the agreed to modifications from the June 9, 2021 Notice as described in Section 2 of this study report.

On March 8, 2022, City Light filed its Initial Study Report (ISR). WDFW, NPS, USFWS, and the Upper Skagit Indian Tribe filed requests for study modification. FERC's August 8, 2022 Determination on Requests for Study Modifications required no modifications to the WQ Monitoring Study.

The WQ Monitoring Study is substantially complete and presents results for an array of water quality variables collected at a large number of sites during 2021 and 2022 . City Light is filing this report of the study efforts with FERC as part of its Updated Study Report (USR) and will supplement results reported herein in a subsequent addendum, which will include data collected through May 2023, consistent with the FERC-approved study plan and commitments made by City Light under the June 9, 2021 Notice.

[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 2021). 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 with regard to study elements contained within the RSP (City Light 2021). For all parameters, data collection under the RSP is taking place over a two-year period extending from June 2021 to May 2023. Specific objectives include the following:

- 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 Dam 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 WQ Monitoring Study are identified below. Please see the FA-01b WQ Model Development Study for commitments pertaining to the development and calibration of the CE-QUAL-W2 model (FA-01b WQ Model Development Study, City Light 2023a), 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 macroinvertebrate sampling program to include the Project reservoirs, Skagit River to the estuary (through reference reach sampling mutually agreed to by City Light 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 LPs to discuss parameters, frequency, monitoring locations, and temporal overlap with existing data.

The water quality sampling program was expanded in 2022 to include additional analytes and locations to support development and calibration of the CE-QUAL-W2 water quality model (FA-01b WQ Model Development Study, City Light 2023a). The expanded sampling supplements ongoing water quality data collection to provide improved boundary conditions for nutrients and organic matter entering from the tributaries and additional model validation data within the reservoirs and the lower Skagit River. Sampling locations, frequencies, and parameters are described in Section 4 of this study report.

In addition, the macroinvertebrate monitoring program was expanded over the 2022-2023 seasons to meet the following objectives:

- Characterize BMI communities in the lentic zones of Ross, Diablo and Gorge lakes, using seasonal PONAR grab samples of lake benthos collected at locations within four reaches of Ross and Diablo lakes, and three reaches of Gorge Lake.
- Compare BMI colonization rates and community composition between the continuously inundated lentic zone and the intermittently inundated varial zone of Ross Lake, using substrate baskets deployed on the reservoir bottom in these zones and then retrieved at two intervals.
- Characterize BMI communities in tributaries of Ross, Diablo, and Gorge lakes, using seasonally collected kicknet samples of tributary benthos.

- Characterize fish prey items present in tributaries of Ross, Diablo, and Gorge lakes, using nets to collect seasonal samples of drifting macroinvertebrates.
- Characterize BMI communities in side-channel habitats of the Skagit River, using nets to collect samples of side-channel benthos.
- Characterize BMI communities in the lower Skagit River using seasonally collected kicknet samples.
- Conduct intensive BMI sampling along transects in the Skagit and Sauk rivers to compare results between regulated and unregulated systems.

The comprehensive macroinvertebrate program, including reservoir and riverine benthic sampling, and invertebrate drift data collections, is designed to explore Project effects in the reservoirs and the Skagit River and to establish baseline data to which potential future sampling results can be compared. Sampling locations, frequencies, and parameters are described in Section 4 of this study report.

# 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 Sedro Woolley, and in the lower Sauk River (Figure 3.0-1). Specific locations of the water quality sampling/measurement sites are shown in Attachment A and discussed in Section 4.1 of this study report.

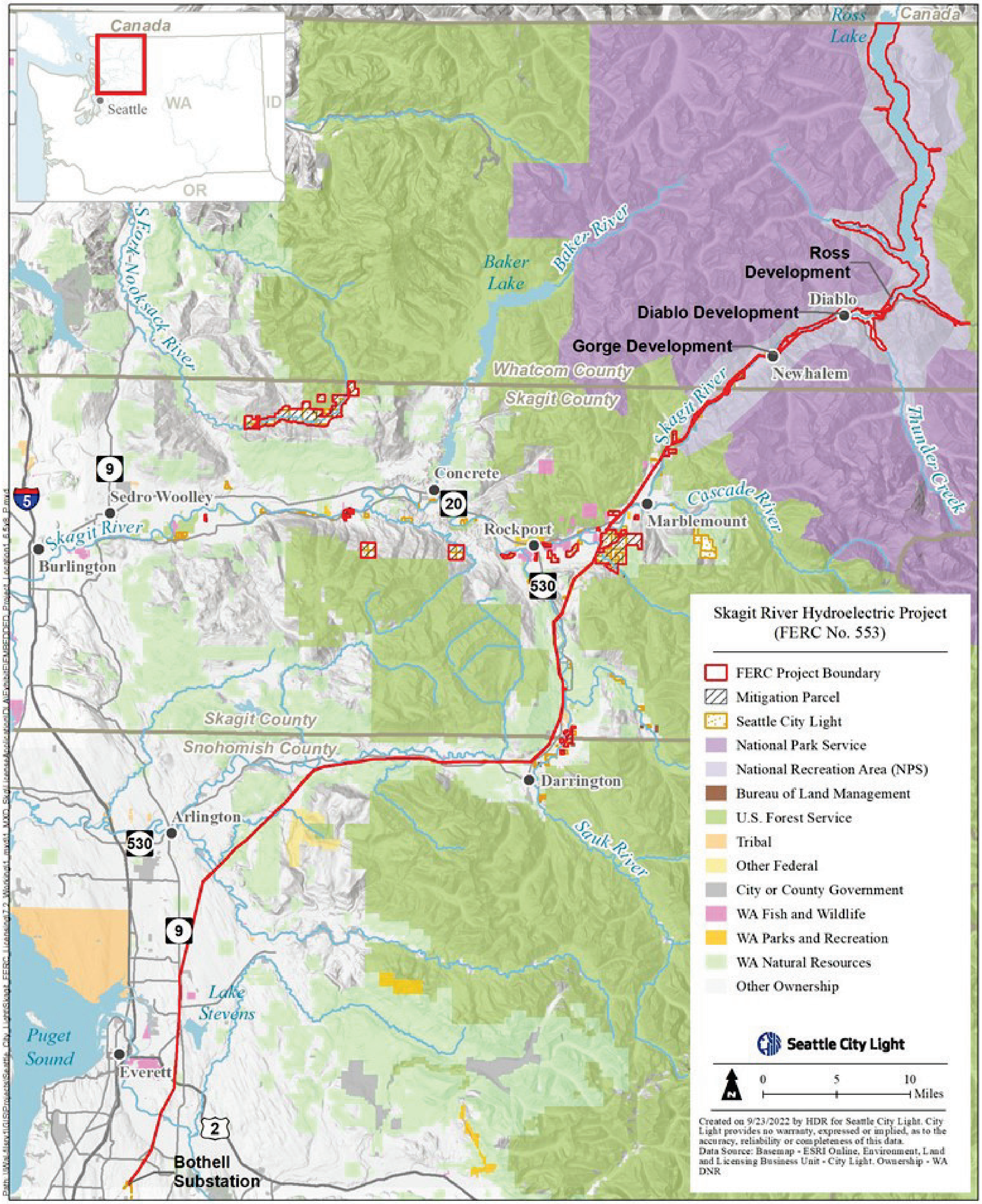



**Figure 3.0-1. Location map of the Skagit River Project.**

# 4.0 METHODS

## 4.1 Field Methods

Per the RSP, the WQ Monitoring Study was 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). As noted in Section 2.0, the expanded water quality and macroinvertebrate monitoring program added a broad suite of analytes for laboratory measurement, and in addition to kick sampling for macroinvertebrates, added benthic invertebrate sampling in Project reservoirs, and drift sampling in selected tributaries. As the WQ Monitoring Study is ongoing through May of 2023; subsequent results will be included in an addendum to this study report. Water quality and macroinvertebrate parameters, sampling type, and sampling frequency vary by location, as summarized in Table 4.1-1 (water quality monitoring), and 4.1-2 (macroinvertebrate monitoring). 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. Field methods for water quality and macroinvertebrate sample collection are presented below, followed by descriptions of sample collection within the following five geographic areas:

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

**Table 4.1-1. Water Quality Monitoring Study sampling parameters, frequency, and methodology by location (sites ordered upstream to downstream).**

| Location (Mapbook Location Number) | Sample Identification | Approximate Lat./Lon. | Purpose | Sampling Frequency | Sampling Method/Type (depth) | Parameter |
|---|---|---|---|---|---|---|
| **Ross Lake** | | | | | | |
| Skagit River at International Boundary (1) | TRIB1 | 49.00022/ -121.074 | Drawdown monitoring, model development | Once in fall and once in winter/spring | Grab sample (1 meter [m], tributary) | Turbidity, TSS |
| US Geologic Survey (USGS) site at international boundary (1) | - | 48.99865/ -121.07790 | Baseline conditions, model development | Monthly from May-Oct; 1-2 samples in winter | Grab sample/*In situ* measurement, depending on parameter (1-m) | Temperature, DO, pH, specific conductance, turbidity, TSS, nutrients, chlorophyll *a*, phytoplankton, carbon, alkalinity |
| Near Hozomeen (77) | ROSS7 | 48.98681/ -121.07361 | Recreational impact | Monthly in Jun, Jul, Aug, and Sep | Grab sample (Surface) | FC |
| Silver Creek confluence (128) | TRIB2 | 48.97023/ -121.104 | Drawdown monitoring, model development | Once in fall and once in winter/spring | Grab sample (1-m, tributary) | Turbidity, TSS |
| Ross Lake shoreline erosional area north (79) | ROSS4 | 48.94838/ -121.08508 | Drawdown monitoring, model development | Once in fall and once in winter/spring | Grab sample (Surface Transect) | Turbidity, TSS |
| Little Beaver (71) | ROSS3 | 48.9274/ -121.0625 | Baseline monitoring, model development | Monthly | Grab sample (1-m, 5-m) | Turbidity, TSS |
| Little Beaver Creek confluence (81) | TRIB3 | 48.91536/ -121.077 | Drawdown monitoring, model development | Once in fall and once in winter/spring | Grab sample (1-m, tributary) | Turbidity, TSS |
| Little Beaver Creek near mouth (81) | TRIB3A | 48.91473/ -121.07505 | Model development | Monthly from May-Oct; 1-2 samples in winter | Grab sample/*In situ* measurement, depending on parameter (1-m) | Temperature, DO, pH, specific conductance, nutrients, chlorophyll *a*, phytoplankton, carbon, alkalinity |
| Near Little Beaver boat access camp (80) | ROSS9 | 48.91784/ -121.12628 | Recreational impact | Monthly in Jun, Jul, Aug, and Sep | Grab sample (Surface) | FC |
| Ross Lake shoreline erosional area central (82) | ROSS5 | 48.89389/ -121.04398 | Drawdown monitoring, model development | Once in fall and once in winter/spring | Grab sample (Surface Transect) | Turbidity, TSS |
| Near Lightning Creek boat access camp (83) | ROSS10 | 48.87629/ -121.01100 | Recreational impact | Monthly in Jun, Jul, Aug, and Sep | Grab sample (Surface) | FC |
| Lightning Creek confluence (85) | TRIB4 | 48.87443/ -121.018 | Drawdown monitoring, model development | Once in fall and once in winter/spring | Grab sample (1-m, tributary) | Turbidity, TSS |
| Lightning Creek near mouth (85) | TRIB4A | 48.87590/ -121.01570 | Model development | Monthly from May-Oct; 1-2 samples in winter | Grab sample/*In situ* measurement, depending on parameter (1-m) | Temperature, DO, pH, specific conductance, nutrients, chlorophyll *a*, phytoplankton, carbon, alkalinity |
| Dry Creek confluence (86) | TRIB5 | 48.85340/ -121.014 | Drawdown monitoring, model development | Once in fall and once in winter/spring | Grab sample (1-m, tributary) | Turbidity, TSS |
| Skymo (84) | ROSS2 | 48.8547/ -121.0308 | Baseline monitoring, model development | Monthly | Grab sample (1-m, 5-m) | Turbidity, TSS |
| Devil's Creek confluence (95) | TRIB6 | 48.82411/ -121.033 | Drawdown monitoring, model development | Once in fall and once in winter/spring | Grab sample (1-m, tributary) | Turbidity, TSS s |
| Pumpkin Mountain (87) | ROSS1 | 48.7904/ -121.0496 | Baseline monitoring, model development | Monthly | Grab sample (1-m, 5-m) | Turbidity, TSS s |
| Ross Lake shoreline erosional area south (88) | ROSS6 | 48.76682/ -121.04427 | Drawdown monitoring, model development | Once in fall and once in winter/spring | Grab sample (Surface Transect) | Turbidity, TSS |
| May Creek confluence (90) | TRIB7 | 48.78624/ -121.030 | Drawdown monitoring, model development | Once in fall and once in winter/spring | Grab sample (1-m, tributary) | Turbidity, TSS |
| Near Big Beaver boat access camp (89) | ROSS1 | 48.77487/ -121.06649 | Recreational impact | Monthly in Jun, Jul, Aug, and Sep | Grab sample (Surface) | FC |
| Big Beaver Creek confluence (9) | TRIB8 | 48.77418/ -121.06419 | Drawdown monitoring, model development | Once in fall and once in winter/spring | Grab sample (1-m, tributary) | Turbidity, TSS |
| Big Beaver Creek near mouth (9) | TRIB8A | 48.77508/ -121.06697 | Model development | Monthly from May-Oct; 1-2 samples in winter | Grab sample/*In situ* measurement, depending on parameter (1-m) | Temperature, DO, pH, specific conductance, nutrients, chlorophyll *a*, phytoplankton, carbon, alkalinity |
| Pierce Creek confluence (91) | TRIB9 | 48.77242/ -121.066 | Drawdown monitoring, model development | Once in fall and once in winter/spring | Grab sample (1-m, tributary) | Turbidity, TSS |
| Roland Creek confluence (93) | TRIB10 | 48.76913/ -121.024 | Drawdown monitoring, model development | Once in fall and once in winter/spring | Grab sample (1-m, tributary) | Turbidity, TSS |
| Ruby Creek Arm (94) | TRIB11 | 48.73004/ -121.02532 | Drawdown monitoring, model development | Once in fall and once in winter/spring | Grab sample (1-m, tributary) | Turbidity, TSS |

| Location (Mapbook Location Number) | Sample Identification | Approximate Lat./Lon. | Purpose | Sampling Frequency | Sampling Method/Type (depth) | Parameter |
|---|---|---|---|---|---|---|
| Ruby Creek near mouth (94) | TRIB11 | 48.71476/ -120.99338 | Model development | Monthly from May-Oct; 1-2 samples in winter | Grab sample/*In situ* measurement, depending on parameter (1-m) | Temperature, DO, pH, specific conductance, turbidity, TSS, nutrients, chlorophyll *a*, phytoplankton, carbon, alkalinity |
| Ross Lake log boom (7) | ROSS12 | 48.73721/ -121.05439 | Model development | Monthly from May-Oct; 1-2 samples in winter at three depths | Grab sample/*In situ* measurement, depending on parameter (3 depths) | Temperature, DO, pH, specific conductance, turbidity, TSS, nutrients, chlorophyll *a*, phytoplankton, carbon, alkalinity |
| Near Ross Lake Resort (162) | ROSS8 | 48.73890/ -121.06072 | Recreational impact | Monthly in Jun, Jul, Aug, and Sep | Grab sample (Surface) | FC |
| **Diablo Lake** | | | | | | |
| Upstream end at Boathouse (28) | DIABLO1 | 48.72961/ -121.07244 | Baseline monitoring, model development | Monthly | *In situ* measurement (Vertical Profile) | Temperature, DO, pH |
| Upstream end (28) | DIABLO1 | 48.72961/ -121.07244 | Baseline monitoring, model development | Monthly | Grab sample (1-m, 5-m) | Turbidity, TSS |
| Main pool (189) | DIABLO7 | 48.71301/ -121.11405 | Model development | Monthly from May-Nov | Tow net | Zooplankton[1] |
| Environmental Learning Center (98) | DIABLO5 | 48.71690/ -121.11940 | Recreational impact | Monthly in Jun, Jul, Aug, and Sep | Grab sample (Surface) | FC |
| Thunder Creek Arm, Colonial Creek confluence (102) | DIABLO6 | 48.69215/ -121.10045 | Drawdown monitoring, model development | Once in fall and once in winter/spring | Grab sample (Surface Transect) | Turbidity, TSS |
| Thunder Creek Arm, Rhode Creek confluence (99) | DIABLO3 | 48.69101/ -121.09552 | Drawdown monitoring, model development | Once in fall and once in winter/spring | Grab sample (Surface Transect) | Turbidity, TSS |
| Thunder Creek Arm (100) | DIABLO4 | 48.69101/ -121.09552 | Recreational impact | Monthly in Jun, Jul, Aug, and Sep | Grab sample (Surface) | FC |
| Thunder Creek Arm (134) | TRIB12 | 48.66826/ -121.06931 | Model development | Monthly from May-Oct; 1-2 samples in winter | Grab sample/*In situ* measurement, depending on parameter (1-m) | Temperature, DO, pH, specific conductance, nutrients, chlorophyll *a*, phytoplankton, carbon, alkalinity |
| Diablo Dam Forebay (96) | DIABLO2 | 48.71489/ -121.13171 | Baseline monitoring, model development | Monthly | *In situ* measurement (Vertical Profile) | Temperature, DO, pH |
| Diablo Dam Forebay (96) | DIABLO2 | 48.71489/ -121.13171 | Baseline monitoring, model development | Monthly | Grab sample (1-m, 5-m) | Turbidity, TSS |
| Diablo Dam Forebay (34) | DIABLO2 | 48.71421/ -121.13134 | Model development | Monthly from May-Oct; 1-2 samples in winter at three depths | Grab sample/*In situ* measurement, depending on parameter (3 depths) | Temperature, DO, pH, specific conductance, nutrients, chlorophyll *a*, phytoplankton, carbon, alkalinity |
| **Gorge Lake** | | | | | | |
| Upstream end (97) | GORGE1 | 48.71188/ -121.14317 | Baseline monitoring, model development | Monthly | *In situ* measurement (Vertical Profile) | Temperature, DO, pH |
| Upstream end (97) | GORGE1 | 48.71188/ -121.14317 | Baseline monitoring, model development | Monthly | Grab sample (1-m, 5-m) | Turbidity, TSS |
| Reflector Bar (181) | GORGE1X | 48.71179278/ -121.1425531 | Model development | Monthly from May-Nov | Tow net | Zooplankton[1] |
| Below the Diablo Powerhouse Outflow (97) | GORGE3 | 48.71188/ -121.14317 | Baseline monitoring | Continuous | Installation of a sonde/probe (Below compensation depth) | TDG |
| Stetattle Creek (46) | STET1 | 48.71694051/ -121.1496877 | Model development | Monthly from May-Oct; 1-2 samples in winter | Grab sample/*In situ* measurement, depending on parameter (1-m) | Temperature, DO, pH, specific conductance, turbidity, TSS, nutrients, chlorophyll *a*, phytoplankton, carbon, alkalinity |
| Gorge Lake downstream of Stetattle (191) | GORGE5 | 48.71335476/ -121.1547201 | Model development | Monthly from May-Nov | Tow net | Zooplankton[1] |
| Log boom (43) | GORGE7 | 48.70020/ -121.19311 | Model development | Monthly from May-Nov | Tow net | Zooplankton[1] |
| Log boom (43) | GORGE7 | 48.69755/ -121.20745 | Model development | Monthly from May-Oct; 1-2 samples in winter | Grab sample/*In situ* measurement, depending on parameter (1-m) | Temperature, DO, pH, specific conductance, nutrients, chlorophyll *a*, phytoplankton, carbon, alkalinity |
| Gorge Dam Forebay (108) | GORGE2 | 48.69777/ -121.20672 | Baseline monitoring, model development | Monthly | *In situ* measurement (Vertical Profile) | Temperature, DO, pH |
| Gorge Dam Forebay (108) | GORGE2 | 48.69777/ -121.20672 | Baseline monitoring, model development | Monthly | Grab sample (1-m, 5-m) | Turbidity, TSS |
| Gorge Dam Forebay (108) | GORGE4 | 48.69777/ -121.20672 | Baseline monitoring | Continuous | Installation of a sonde/probe (Below compensation depth) | TDG |

| Location (Mapbook Location Number) | Sample Identification | Approximate Lat./Lon. | Purpose | Sampling Frequency | Sampling Method/Type (depth) | Parameter |
|---|---|---|---|---|---|---|
| **Gorge Bypass Reach** | | | | | | |
| Below Gorge Dam in plunge pool (109) | BYPASS1 | 48.69783/ -121.20898 | Baseline monitoring | Episodic[2] | *In situ* measurement (Below compensation depth) | Temperature, DO, turbidity, TDG |
| Gorge Dam access bridge (192) | BYPASS4 | 48.6966169/ -121.2131147 | Spill monitoring | Opportunistically | *In situ* measurement (Below compensation depth) | TDG |
| ≈ 1.5 miles above Gorge Powerhouse (111) | BYPASS2 | 48.69030/ -121.22680 | Baseline monitoring | Episodic[2] | *In situ* measurement (Below compensation depth) | Temperature, DO, turbidity, TDG |
| ≈ 0.6 miles above Gorge Powerhouse (110) | BYPASS3 | 48.68415/ -121.24216 | Baseline monitoring | Episodic[2] | *In situ* measurement (Below compensation depth) | Temperature, DO, turbidity, TDG |
| Gorge Powerhouse access bridge (174) | BYPASS5 | 48.6757123/ -121.2416487 | Spill monitoring | Opportunistically | *In situ* measurement (Below compensation depth) | TDG |
| **Skagit River – Newhalem Area** | | | | | | |
| Ladder Creek Falls Bridge (113) | LADDER1 | 48.67507/ -121.24010 | Spill monitoring | Opportunistically | *In situ* measurement (Below compensation depth) | TDG |
| Immediately below Gorge Powerhouse, right bank (112) | PHOUSE1 | 48.67520/ -121.24052 | Baseline monitoring | Continuous | Installation of a sonde/probe (Below compensation depth) | Temperature, DO, turbidity, TDG, pH |
| Immediately below Gorge Powerhouse, right bank (112) | PHOUSE2 | 48.67520/ -121.24052 | Baseline monitoring | Opportunistically | Grab sample (1-m) | TSS |
| Immediately below Gorge Powerhouse, right bank (112) | PHOUSE1 | 48.67520/ -121.24052 | Model development | Monthly from May-Nov | Drift net | Zooplankton |
| Below Gorge Powerhouse (112) | PHOUSE1 | 48.67520/ -121.24052 | Model development | Monthly from May-Nov | Grab sample (Bottom) | Periphyton |
| Bridge to Trail of the Cedars (69) | CEDARS1 | 48.67153/ -12124600 | Spill monitoring | Opportunistically | *In situ* measurement (Below compensation depth) | TDG |
| Newhalem Creek near mouth (68) | NEWCG | 48.67132/ -121.25633 | Model development | Monthly from May-Oct; 1-2 samples in winter | Grab sample/*In situ* measurement, depending on parameter (1-m) | Temperature, DO, pH, specific conductance, turbidity, TSS, nutrients, chlorophyll *a*, phytoplankton, carbon, alkalinity |
| Bridge at Newhalem Campground (161) | NEWCG1 | 48.67238/ -12126104 | Spill monitoring | Opportunistically | *In situ* measurement (Below compensation depth) | TDG |
| **Skagit River within National Park Boundary** | | | | | | |
| Project River Mile (PRM) 91.6 (114) | SKAGIT2 | 48.65122/ -121.29099 | Baseline monitoring, model development | Continuous | Installation of a sonde/probe (1-m) | Temperature |
| Side Channel Habitat near PRM 90.0 (163) | SKAGIT2SC | 48.641660/ -121.309870 | Baseline monitoring, model development | Continuous | Installation of a sonde/probe (1-m) | Temperature |
| PRM 85.9 (145) | SKAGIT3 | 48.60422/ -121.35973 | Baseline monitoring, model development | Continuous | Installation of a sonde/probe (1-m) | Temperature |
| Above Alma Creek (145) | SKAGIT3 | 48.60439/ -121.35964 | Model development | Continuous, three 3-week durations, May-Oct | Installation of a sonde/probe (1-m) | Temperature, DO, pH, specific conductance, turbidity |
| Above Alma Creek (145) | SKAGIT3 | 48.60439/ -121.35964 | Model development | Monthly from May-Oct; 1-2 samples in winter | Grab sample/*In situ* measurement, depending on parameter (1-m) | Temperature, DO, pH, specific conductance, turbidity, TSS, nutrients, chlorophyll *a*, phytoplankton, carbon, alkalinity |
| Above Alma Creek (145) | SKAGIT3 | 48.60439/ -121.35964 | Model development | Monthly from May-Nov | Grab sample (Bottom) | Periphyton |
| **Skagit River Downstream of National Park Boundary** | | | | | | |
| Skagit River at Marblemount (148) | MARB1 | 48.53267148/ -121.4295083 | Model development | Monthly from May-Oct; 1-2 samples in winter | Grab sample (1-m) | Chlorophyll *a*, phytoplankton, alkalinity |
| Cascade River at Marblemount (154) | CASC1 | 48.53267148/ -121.4256403 | Model development | Monthly from May-Oct; 1-2 samples in winter | Grab sample/*In situ* measurement, depending on parameter (1-m) | Temperature, DO, pH, specific conductance, turbidity, TSS, nutrients, chlorophyll *a*, phytoplankton, carbon, alkalinity |
| PRM 75.6 (118) | SKAGIT4 | 48.50647162/ -121.4686583 | Baseline monitoring, model development | Continuous | Installation of a sonde/probe (1-m) | Temperature |
| Skagit River downstream of Marblemount (118) | SKAGIT4 | 48.50647162/ -121.4686583 | Model development | Continuous, three 3-week durations, May-Oct | Installation of a sonde/probe (1-m) | Temperature, DO, pH, specific conductance, turbidity |

| Location (Mapbook Location Number) | Sample Identification | Approximate Lat./Lon. | Purpose | Sampling Frequency | Sampling Method/Type (depth) | Parameter |
|---|---|---|---|---|---|---|
| Skagit River downstream of Marblemount (118) | SKAGIT4 | 48.50647162/ -121.4686583 | Model development | Monthly from May-Oct; 1-2 samples in winter | Grab sample/*In situ* measurement, depending on parameter (1-m) | Temperature, DO, pH, specific conductance, turbidity, TSS, nutrients, chlorophyll *a*, phytoplankton, carbon, alkalinity |
| Skagit River downstream of Marblemount (118) | SKAGIT4 | 48.50647162/ -121.4686583 | Model development | Monthly from May-Nov | Grab sample (Bottom) | Periphyton |
| Side channel habitat near PRM 75.6 (119) | SKAGIT4SC | 48.496670/ -121.53117 | Baseline monitoring, model development | Continuous | Installation of a sonde/probe | Temperature |
| PRM 69.3 (122) | SKAGIT5 | 48.48548973/ -121.5734032 | Baseline monitoring, model development | Continuous | Installation of a sonde/probe (1-m) | Temperature |
| Skagit River upstream of Sauk (122) | SKAGIT5 | 48.48548973/ -121.5734032 | Model development | Monthly from May-Oct; 1-2 samples in winter | Grab sample/*In situ* measurement, depending on parameter (1-m) | Temperature, DO, pH, specific conductance, turbidity, TSS, nutrients, chlorophyll *a*, phytoplankton, carbon, alkalinity |
| PRM 60.8 (124) | SKAGIT6 | 48.504480/ -121.706440 | Baseline monitoring, model development | Continuous | Installation of a sonde/probe (1-m) | Temperature |
| Side channel habitat near PRM 60.8 (171) | SKAGIT6SC | 48.518206/ -121.713024 | Baseline monitoring, model development | Continuous | Installation of a sonde/probe (1-m) | Temperature |
| Baker River (156) | BAKER1 | 48.53889474/ -121.7430003 | Model development | Monthly from May-Oct; 1-2 samples in winter | Grab sample/*In situ* measurement, depending on parameter (1-m) | Temperature, DO, pH, specific conductance, turbidity, TSS, nutrients, chlorophyll *a*, phytoplankton, carbon, alkalinity |
| PRM 54.5 (155) | SKAGIT7 | 48.52555049/ -121.7718681 | Baseline monitoring, model development | Continuous | Installation of a sonde/probe (1-m) | Temperature |
| Skagit River near Concrete (155) | SKAGIT7 | 48.52555049/ -121.7718681 | Model development | Monthly from May-Oct; 1-2 samples in winter | Grab sample/*In situ* measurement, depending on parameter (1-m) | Temperature, DO, pH, specific conductance, turbidity, TSS, nutrients, chlorophyll *a*, phytoplankton, carbon, alkalinity |
| Skagit River near Concrete (155) | SKAGIT7 | 48.52555049/ -121.7718681 | Model development | Continuous, three 3-week durations, May-Oct | Installation of a sonde/probe (1-m) | Temperature, DO, pH, specific conductance, turbidity |
| Skagit River near Concrete (155) | SKAGIT7 | 48.52555049/ -121.7718681 | Model development | Monthly from May-Nov | Grab sample (Bottom) | Periphyton |
| Sauk USGS RM 5.4 (120) | SAUK1 | 48.41997441/ -121.5646661 | Baseline monitoring, model development | Continuous | Installation of a sonde/probe (1-m) | Temperature |
| Sauk USGS RM 5.4 (120) | SAUK1 | 48.41997441/ -121.5646661 | Model development | Monthly from May-Oct; 1-2 samples in winter | Grab sample/*In situ* measurement, depending on parameter (1-m) | Temperature, DO, pH, specific conductance, turbidity, TSS, nutrients, chlorophyll *a*, phytoplankton, carbon, alkalinity |
| Sauk River upstream of Suiattle River (166) | SAUK2 | 48.328771/ -121.547220 | Baseline monitoring, model development | Continuous | Installation of a sonde/probe (1-m) | Temperature |
| Sauk River upstream of Suiattle River (166) | SAUK2 | 48.328771/ -121.547220 | Baseline monitoring, model development | Quarterly | Grab sample (1-m) | Nutrients |
| Side Channel Habitat Sauk upstream of Suiattle River (176) | SAUK2SC | 48.328857/ -121.547570 | Baseline monitoring, model development | Continuous | Installation of a sonde/probe (1-m) | Temperature |
| Skagit River near Hamilton, PRM 42.2 (167) | SKAGIT8 | 48.5183921/ -121.9596186 | Baseline monitoring, model development | Continuous | Installation of a sonde/probe (1-m) | Temperature |
| Side Channel Habitat near Skagit near Hamilton, PRM 42.2 (170) | SKAGIT8SC | 48.52018351/ -121.9596939 | Baseline monitoring, model development | Continuous | Installation of a sonde/probe (1-m) | Temperature |
| Skagit near State Route (SR) 9 Bridge, PRM 23.1 (168) | SKAGIT9 | 48.48130834/ -122.2471543 | Baseline monitoring, model development | Continuous | Installation of a sonde/probe (1-m) | Temperature |

Notes:
Nutrients = $NH_4$, $NO_x$, TKN/TN, Orthophosphate, TP.
Carbon = TOC, POC, DOC, CBOD.
Remaining sampling events as of October 1, 2022. Completed sampling is noted as N/A.
Given the loss of monitoring equipment due to the November 2021 flood, and the highly dynamic condition of the Gorge bypass reach, continuous monitoring has been replaced with episodic monitoring; monitoring also accounts for the safety of field personnel.
Zooplankton in Diablo and Gorge lakes will be sampled by NPS.

**Table 4.1-2. Water Quality Monitoring Study macroinvertebrate sampling methods and frequency by location (sites ordered upstream to downstream).**

| Location (Mapbook Location Number) | Sample Identification | Approximate Lat./Lon. | Purpose | Sampling Frequency | Sampling Method/Type | Method |
|---|---|---|---|---|---|---|
| **Ross Lake** | | | | | | |
| Skagit Mainstem Confluence (185) | TRIB1X | 49.00022/ -121.074[1] | Examine mainstem inflow prey communities at international border | Once, in May 2023 | Tributary Benthic | Kicknet |
| Skagit Mainstem Confluence (185) | TRIB1X | 49.00022/ -121.074[1] | Examine mainstem inflow prey communities at international border | Once, in May 2023 | Tributary Drift | Drift Net |
| Hozomeen (186) | HOZO1X | 48.98699/ -121.0717[1] | Examine tributary prey communities | Once, in May 2023 | Tributary Benthic | Kicknet |
| Hozomeen (186) | HOZO1X | 48.98699/ -121.0717[1] | Examine tributary prey communities | Once, in May 2023 | Tributary Drift | Drift Net |
| Hozomeen (213) | Hoz-Ponar-HiVar | 48.938236/ -121.080353 | Examine prey communities in high varial zone of reservoir | Every 6 weeks, May – Oct (4x/year) 2022 | Lentic Grab | PONAR |
| Hozomeen (214) | Hoz-Ponar-LowVar | 48.941086/ -121.080858 | Examine prey communities in low varial zone of reservoir | Every 6 weeks, May – Oct (4x/year) 2022 | Lentic Grab | PONAR |
| Hozomeen (215) | Hoz-Ponar-PermIn | 48.941861/ -121.080458 | Examine prey communities in inundated zone of reservoir | Every 6 weeks, May – Oct (4x/year) 2022 | Lentic Grab | PONAR |
| Hozomeen (201) | Hoz-Basket-HiVar | 48.940542/ -121.080783 | Explore colonization rate and composition in high varial zone of reservoir | Deployment at full pool. Removal of control and treatment will depend on pool levels and will target near full-pool, mid-pool, and low-pool conditions | Benthic Colonization | Rock Basket |
| Hozomeen (202) | Hoz-Basket-LowVar | 48.941114/ -121.080192 | Explore colonization rate and composition in low varial zone of reservoir | Deployment at full pool. Removal of control and treatment will depend on pool levels and will target near full-pool, mid-pool, and low-pool conditions | Benthic Colonization | Rock Basket |
| Hozomeen (203) | Hoz-Basket-PermIn | 48.941753/ -121.078786 | Explore colonization rate and composition in low varial zone of reservoir | Deployment at full pool. Removal of control and treatment will depend on pool levels and will target near full-pool, mid-pool, and low-pool conditions | Benthic Colonization | Rock Basket |
| Silver (128) | TRIB2X | 48.96965112/ -121.1045833[1] | Examine tributary prey communities above full pool and lower end of varial zone during drawdown | Once, in May 2023 | Tributary Benthic | Kicknet |
| Silver (128) | TRIB2X | 48.96965112/ -121.1045833[1] | Examine tributary prey communities above full pool and lower end of varial zone during drawdown | Once, in May 2023 | Tributary Drift | Drift Net |
| Little Beaver (81) | TRIB3X | 48.91536/ -121.077[1] | Examine tributary prey communities above full pool and lower end of varial zone during drawdown | Once, in May 2023 | Tributary Benthic | Kicknet |
| Little Beaver (81) | TRIB3X | 48.91536/ -121.077[1] | Examine tributary prey communities above full pool and lower end of varial zone during drawdown | Once, in May 2023 | Tributary Drift | Drift Net |
| Desolation (210) | Des-Ponar-HiVar | 48.889569/ -121.039903 | Examine prey communities in high varial zone of reservoir | Every 6 weeks, May – Oct (4x/year) 2022 | Lentic Grab | PONAR |
| Desolation (211) | Des-Ponar-LowVar | 48.889103/ -121.040539 | Examine prey communities in low varial zone of reservoir | Every 6 weeks, May – Oct (4x/year) 2022 | Lentic Grab | PONAR |

| Location (Mapbook Location Number) | Sample Identification | Approximate Lat./Lon. | Purpose | Sampling Frequency | Sampling Method/Type | Method |
|---|---|---|---|---|---|---|
| Desolation (212) | Des-Ponar-PermIn | 48.887781/ -121.040031 | Examine prey communities in inundated zone of reservoir | Every 6 weeks, May – Oct (4x/year) 2022 | Lentic Grab | PONAR |
| Desolation (198) | Des-Basket-HiVar | 48.888878/ -121.040158 | Explore colonization rate and composition in high varial zone of reservoir | Deployment at full pool. Removal of control and treatment will depend on pool levels and will target near full-pool, mid-pool, and low-pool conditions | Benthic Colonization | Rock Basket |
| Desolation (199x) | Des-Basket-LowVar | 48.888944/ -121.040461 | Explore colonization rate and composition in low varial zone | Deployment at full pool. Removal of control and treatment will depend on pool levels and will target near full-pool, mid-pool, and low-pool conditions | Benthic Colonization | Rock Basket |
| Desolation (200) | Des-Basket-PermIn | 48.889131/ -121.041947 | Explore colonization rate and composition in inundated zone | Deployment at full pool. Removal of control and treatment will depend on pool levels and will target near full-pool, mid-pool, and low-pool conditions | Benthic Colonization | Rock Basket |
| Lightning (187) | TRIB4X | 48.87443/ -121.018[1] | Examine tributary prey communities above full pool and lower end of varial zone | Once, in May 2023 | Tributary Benthic | Kicknet |
| Lightning (187) | TRIB4X | 48.87443/ -121.018[1] | Examine tributary prey communities above full pool and lower end of varial zone | Once, in May 2023 | Tributary Drift | Drift Net |
| Dry(86) | TRIB5X | 48.85341738/ -121.0135648[1] | Examine tributary prey communities above full pool and lower end of varial zone | Once, in May 2023 | Tributary Benthic | Kicknet |
| Dry (86) | TRIB5X | 48.85341738/ -121.0135648[1] | Examine tributary prey communities above full pool and lower end of varial zone | Once, in May 2023 | Tributary Drift | Drift Net |
| Pumpkin Mountain (207) | Pump-Ponar-HiVar | 48.784842/ -121.051972 | Examine prey communities in high varial zone of reservoir | Every 6 weeks, May – Oct (4x/year) 2022 | Lentic Grab | PONAR |
| Pumpkin Mountain (208) | Pump-Ponar-LowVar | 48.785553/ -121.051794 | Examine prey communities in low varial zone of reservoir | Every 6 weeks, May – Oct (4x/year) 2022 | Lentic Grab | PONAR |
| Pumpkin Mountain (209) | Pump-Ponar-PermIn | 48.786847/ -121.052403 | Examine prey communities in inundated zone of reservoir | Every 6 weeks, May – Oct (4x/year) 2022 | Lentic Grab | PONAR |
| Pumpkin Mountain (195) | Pump-Basket-HiVar | 48.785169/ -121.051811 | Explore colonization rate and composition in high varial zone of reservoir | Deployment at full pool. Removal of control and treatment will depend on pool levels and will target near full-pool, mid-pool, and low-pool conditions | Benthic Colonization | Rock Basket |
| Pumpkin Mountain (196) | Pump-Basket-LowVar | 48.785453/ -121.051547 | Explore colonization rate and composition in low varial zone of reservoir | Deployment at full pool. Removal of control and treatment will depend on pool levels and will target near full-pool, mid-pool, and low-pool conditions | Benthic Colonization | Rock Basket |
| Pumpkin Mountain (197) | Pump-Basket-PermIn | 48.785778/ -121.051303 | Explore colonization rate and composition in inundated zone | Deployment at full pool. Removal of control and treatment will depend on pool levels and will target near full-pool, mid-pool, and low-pool conditions | Benthic Colonization | Rock Basket |

| Location (Mapbook Location Number) | Sample Identification | Approximate Lat./Lon. | Purpose | Sampling Frequency | Sampling Method/Type | Method |
|---|---|---|---|---|---|---|
| Big Beaver (92) | TRIB8X | 48.77470409/ -121.0645115[1] | Examine tributary prey communities above full pool and lower end of varial zone | Once, in May 2023 | Tributary Benthic | Kicknet |
| Big Beaver (92) | TRIB8X | 48.77470409/ -121.0645115[1] | Examine tributary prey communities above full pool and lower end of varial zone | Once, in May 2023 | Tributary Drift | Drift Net |
| Roland (93) | TRIB10X | 48.7691443/ -121.0241022[1] | Examine tributary prey communities above full pool and lower end of varial zone | Once, in May 2023 | Tributary Benthic | Kicknet |
| Roland (93) | TRIB10X | 48.7691443/ -121.0241022[1] | Examine tributary prey communities above full pool and lower end of varial zone | Once, in May 2023 | Tributary Drift | Drift Net |
| Ruby Creek (94) | TRIB11X | 48.71476302/ -120.9933835[1] | Examine tributary prey communities above full pool and lower end of varial zone | Once, in May 2023 | Tributary Benthic | Kicknet |
| Ruby Creek (94) | TRIB11X | 48.71476302/ -120.9933835[1] | Examine tributary prey communities above full pool and lower end of varial zone | Once, in May 2023 | Tributary Drift | Drift Net |
| Ruby Arm (204) | Ruby-Ponar-HiVar | 48.731608/ -121.039194 | Characterize prey communities in high varial zone | Every 6 weeks, May – Oct (4x/year) 2022 | Lentic Grab | PONAR |
| Ruby Arm (205) | Ruby-Ponar-LowVar | 48.731625/ -121.039183 | Characterize prey communities in low varial zone | Every 6 weeks, May – Oct (4x/year) 2022 | Lentic Grab | PONAR |
| Ruby Arm (206) | Ruby-Ponar-PermIn | 48.731650/ -121.039169 | Characterize prey communities in inundated zone | Every 6 weeks, May – Oct (4x/year) 2022 | Lentic Grab | PONAR |
| Ruby Arm (190) | Ruby-Basket-HiVar | 48.736542/ -121.039864 | Colonization rate and composition in high varial zone | Deployment at full pool. Removal of control and treatment will depend on pool levels and will target near full-pool, mid-pool, and low-pool conditions | Benthic Colonization | Rock Basket |
| Ruby Arm (193) | Ruby-Basket-LowVar | 48.735997/ -121.040211 | Colonization rate and composition in low varial zone | Deployment at full pool. Removal of control and treatment will depend on pool levels and will target near full-pool, mid-pool, and low-pool conditions | Benthic Colonization | Rock Basket |
| Ruby Arm (194) | Ruby-Basket-PermIn | 48.735394/ -121.040236 | Colonization rate and composition in inundated zone | Deployment at full pool. Removal of control and treatment will depend on pool levels and will target near full-pool, mid-pool, and low-pool conditions | Benthic Colonization | Rock Basket |
| **Diablo Lake** | | | | | | |
| Skagit Arm (217) | SKA-Ponar-PermIn | 48.728644/ -121.072558 | Characterize prey communities in inundated zone | Monthly, Mar – Oct (6x/year) | Lentic Grab | PONAR |
| Thunder South (216) | THS-Ponar-PermIn | 48.691233/ -121.094581 | Characterize prey communities in inundated zone | Monthly, Mar – Oct (6x/year) | Lentic Grab | PONAR |
| Thunder North (218) | THN-Ponar-PermIn | 48.709875/ -121.099950 | Characterize prey communities in inundated zone | Monthly, Mar – Oct (6x/year) | Lentic Grab | PONAR |
| Main Basin (219) | MNB-Ponar-PermIn | 48.717344/ -121.100558 | Characterize prey communities in inundated zone | Monthly, Mar – Oct (6x/year) | Lentic Grab | PONAR |
| Thunder Creek (134) | TRIB12X | 48.66826/ -121.06931[1] | Characterize tributary prey communities | Every 6 weeks, Aug – Oct (4x/year) | Tributary Benthic | Kicknet |
| Thunder Creek (134) | TRIB12X | 48.66826/ -121.06931[1] | Characterize tributary prey communities | Every 6 weeks, Aug – Oct (4x/year) | Tributary Drift | Drift Net |
| **Gorge Lake** | | | | | | |
| Reflector Bar (181) | GORGE1X | 48.71179278/ -121.1425531 | Characterize prey communities in inundated zone | Monthly, Mar – Oct (6x/year) | Lentic Grab | PONAR |

| Location (Mapbook Location Number) | Sample Identification | Approximate Lat./Lon. | Purpose | Sampling Frequency | Sampling Method/Type | Method |
|---|---|---|---|---|---|---|
| Stetattle confluence (183) | GORGE6X | 48.716667/ -121.148925 | Characterize prey communities in inundated zone | Monthly, Mar – Oct (6x/year) | Lentic Grab | PONAR or Kicknet |
| Stetattle (182) | STET1X | 48.717181/ -121.149881 | Characterize tributary prey communities | Every 6 weeks, May – Oct (4x/year) | Tributary Benthic | Kicknet |
| Stetattle (182) | STET1X | 48.717181/ -121.149881 | Characterize tributary prey communities | Every 6 weeks, May – Oct (4x/year) | Tributary Drift | Drift Net |
| West Zone (108) | GORGE2X | 48.69777/ -121.20672 | Characterize prey communities in inundated zone | Monthly, Mar – Oct (6x/year) | Lentic Grab | PONAR |
| **Gorge Bypass Reach** | | | | | | |
| ≈ above Gorge Powerhouse, below first passage impediment (173) | BYPASS3X | 48.676745/ -121.242275 | Characterize bypass reach prey communities | Every 6 weeks, May – Oct (4x), once in winter (1x) | River Benthic | Kicknet |
| ≈ above Gorge Powerhouse, below first passage impediment (173) | BYPASS3X | 48.676745/ -121.242275 | Characterize bypass reach prey communities | Every 6 weeks, May – Oct (4x), once in winter (1x) | River Drift | Drift Net |
| **Skagit River within National Park Boundary** | | | | | | |
| PRM 90.0 (164) | SKAGIT2X | 48.64175/ -121.30958 | Characterize main channel prey communities | Every 6 weeks, May – Oct (4x), once in winter (1x) | River Benthic | Kicknet |
| PRM 90.0 (164) | SKAGIT2X | 48.64175/ -121.30958 | Characterize main channel prey communities | Every 6 weeks, May – Oct (4x), once in winter (1x) | River Drift | Drift Net |
| Side Channel Habitat near PRM 90.0 (163) | SKAGIT2SC | 48.641660/ -121.309870 | Characterize side channel prey communities | Every 6 weeks, May – Oct (4x), once in winter (1x) | Side-Channel Benthic | PONAR or Kicknet, site dependent |
| PRM 85.6 (117) | SKAGIT3X | 48.60422/ -121.35973 | Characterize main channel prey communities | Every 6 weeks, May – Oct (4x/year) | River Benthic | Kicknet |
| PRM 85.6 (117) | SKAGIT3X | 48.60422/ -121.35973 | Characterize main channel prey communities | Every 6 weeks, May – Oct (4x/year) | River Drift | Drift Net |
| **Skagit River downstream of National Park Boundary** | | | | | | |
| PRM 72.0 (175) | SKAGIT4X | 48.50647162/ -121.4686583 | Compare BMI in regulated vs unregulated systems | Every 2 weeks, July – October (9x); Every 4 weeks, March – June, Nov – Dec (6x) | Intensive River Benthic | Kicknet Transect |
| PRM 72.0 (175) | SKAGIT4X | 48.50647162/ -121.4686583 | Characterize main channel prey communities | Every 6 weeks, May – Oct (4x), once in winter (1x) | River Drift | Drift Net |
| Side channel habitat near PRM 72.0 (119) | SKAGIT4SC | 48.496670/ -121.53117 | Compare BMI in regulated vs unregulated systems | Every 2 weeks, July – October (9x); Every 4 weeks, March – June, Nov – Dec (6x) | Intensive Side-Channel Benthic | PONAR or Kicknet, site dependent |
| PRM 69.3 (123) | SKAGIT5X | 48.48548973/ -121.5734032 | Characterize main channel prey communities | Every 6 weeks, May – Oct (4x/year) | River Benthic | Kicknet |
| PRM 69.3 (123) | SKAGIT5X | 48.48548973/ -121.5734032 | Characterize main channel prey communities | Every 6 weeks, May – Oct (4x/year) | River Drift | Drift Net |
| PRM 59.7 (125) | SKAGIT6X | 48.504480/ -121.706440 | Characterize main channel prey communities | Every 6 weeks, May – Oct (4x), once in winter (1x) | River Benthic | Kicknet |
| PRM 59.7 (125) | SKAGIT6X | 48.504480/ -121.706440 | Characterize main channel prey communities | Every 6 weeks, May – Oct (4x), once in winter (1x) | River Drift | Drift Net |
| Side channel habitat near PRM 59.7 (171) | SKAGIT6SC | 48.518206/ -121.713024 | Characterize side channel prey communities | Every 6 weeks, May – Oct (4x/year) | Side-Channel Benthic | PONAR or Kicknet, site dependent |
| PRM 54.5 (127) | SKAGIT7X | 48.52555049/ -121.7718681 | Characterize main channel prey communities | Every 6 weeks, May – Oct (4x/year) | River Benthic | Kicknet |
| PRM 54.5 (127) | SKAGIT7X | 48.52555049/ -121.7718681 | Characterize main channel prey communities | Every 6 weeks, May – Oct (4x/year) | River Drift | Drift Net |
| Skagit River near Hamilton, PRM 42.2 (167) | SKAGIT8X | 48.5183921/ -121.9596186 | Characterize main channel prey communities | Every 6 weeks, May – Oct (4x/year) | River Benthic | Kicknet |
| Skagit River near Hamilton, PRM 42.2 (167) | SKAGIT8X | 48.5183921/ -121.9596186 | Characterize main channel prey communities | Every 6 weeks, May – Oct (4x/year) | River Drift | Drift Net |
| Side channel habitat near Skagit River near Hamilton, PRM 42.2 (170) | SKAGIT8SC | 48.52018351/ -121.9596939 | Characterize side channel prey communities | Every 6 weeks, May – Oct (4x/year) | Side-Channel Benthic | PONAR or Kicknet, site dependent |

| Location (Mapbook Location Number) | Sample Identification | Approximate Lat./Lon. | Purpose | Sampling Frequency | Sampling Method/Type | Method |
|---|---|---|---|---|---|---|
| Skagit River near SR 9 Bridge, PRM 23.1 (168) | SKAGIT9X | 48.48130834/ -122.2471543 | Characterize main channel prey communities | Every 6 weeks, May – Oct (4x/year) | River Benthic | Kicknet |
| Skagit River near SR 9 bridge, PRM 23.1 (168) | SKAGIT9X | 48.48130834/ -122.2471543 | Characterize main channel prey communities | Every 6 weeks, May – Oct (4x/year) | River Drift | Drift Net |
| **Sauk River** | | | | | | |
| Sauk RM 5.4 (121) | SAUK1X | 48.4081692/ -121.5558766 | Characterize main channel prey communities | Every 6 weeks, May – Oct (4x/year) | Tributary Benthic | Kicknet |
| Sauk RM 5.4 (121) | SAUK1X | 48.407934/ -121.556501 | Characterize main channel prey communities | Every 6 weeks, May – Oct (4x/year) | Tributary Drift | Drift Net |
| Sauk River upstream of Suiattle River (176) | SAUK2X | 48.328771/ -121.547220 | Compare BMI in regulated vs unregulated systems | Every 2 weeks, July – October (9x); Every 4 weeks, March – June, Nov – Dec (6x) | Intensive Tributary Benthic | Kicknet Transect |
| Side channel habitat Sauk River upstream of Suiattle River (166) | SAUK2SC | 48.328857/ -121.547570 | Compare BMI in regulated vs unregulated systems | Every 2 weeks, July – October (9x); Every 4 weeks, March – June, Nov – Dec (6x) | Intensive Side-Channel Benthic | PONAR or Kicknet, site dependent |

Notes: Remaining sampling events as of October 1, 2022.

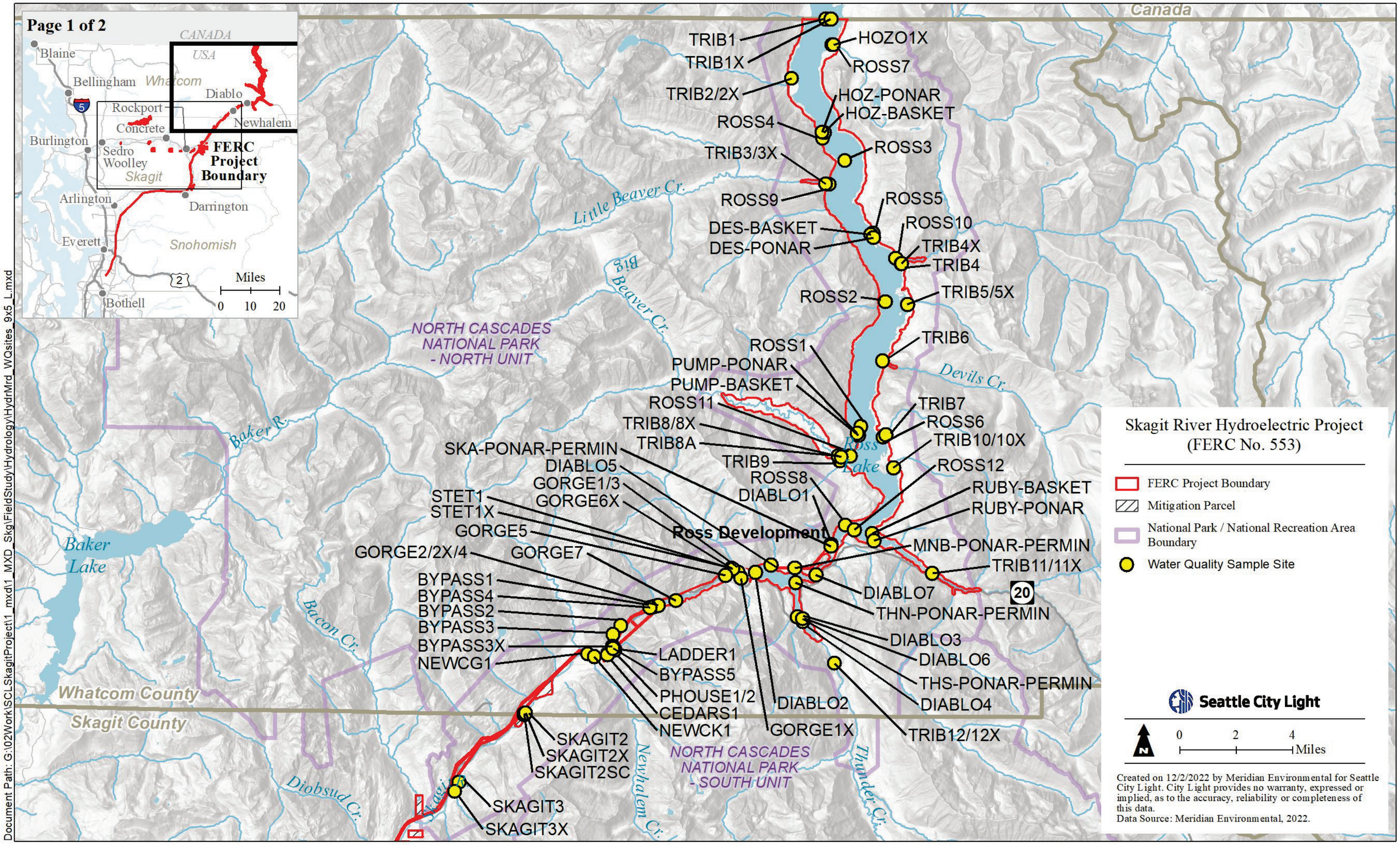



**Figure 4.1-1. Map of water quality and BMI/invertebrate drift monitoring locations in Ross, Diablo, and Gorge lakes, the Gorge bypass reach, Gorge Powerhouse, and mainstem Skagit River (page 1 of 2).**

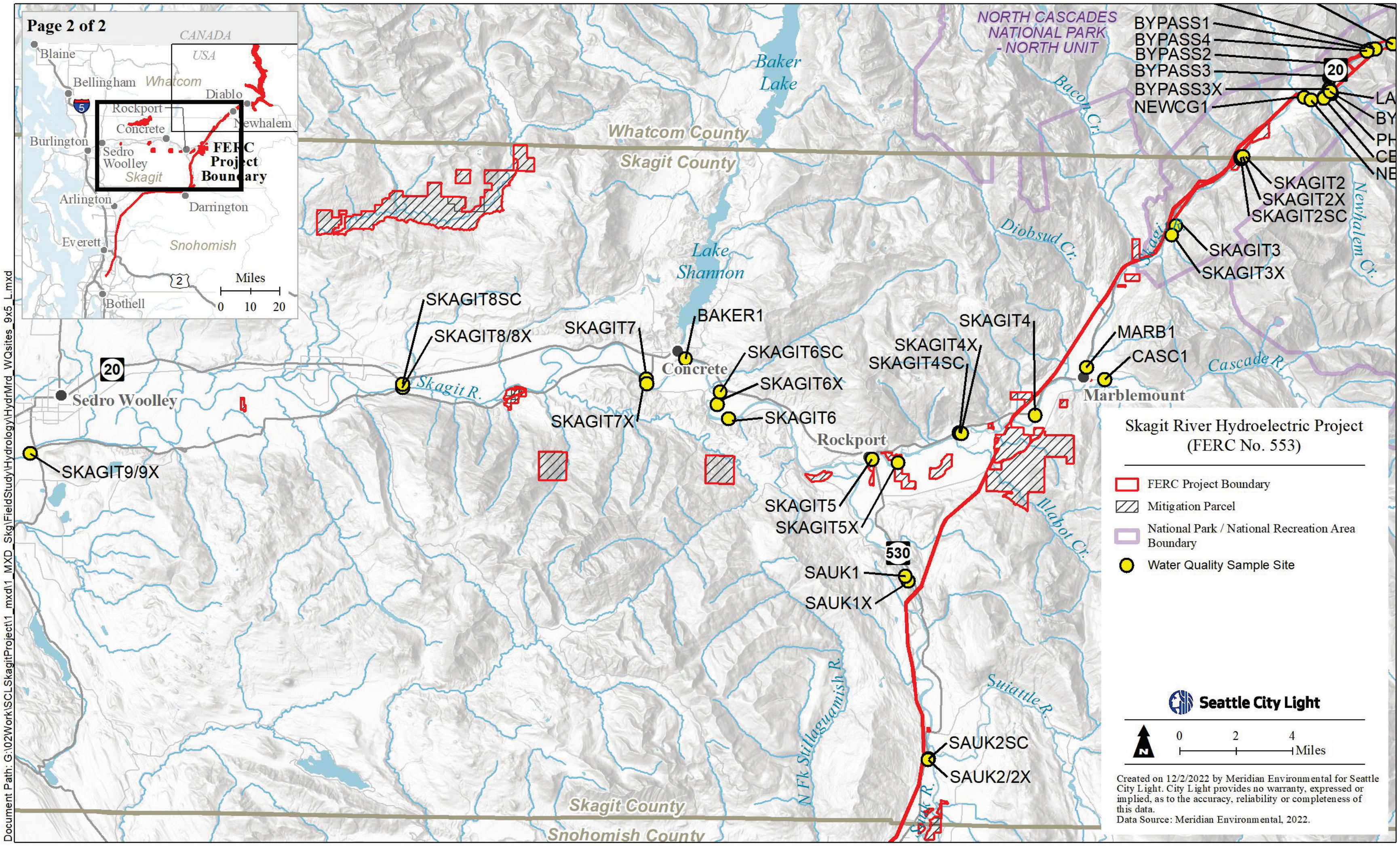



**Figure 4.1-2. Map of water quality and BMI/invertebrate drift monitoring locations in the Gorge bypass reach, Gorge Powerhouse, Sauk River, and mainstem Skagit River (page 2 of 2).**

As discussed in the sections below, water quality data are collected at each site using either *in situ* monitoring or grab sampling for laboratory analysis. Macroinvertebrates are collected using a D-frame kicknet, drift net, PONAR sampler, or benthic colonization basket depending on the site.

Field methods for the various components of the monitoring program adhere to relevant Ecology Standard Operating Procedures (SOP; Ecology 2006; 2017; 2018a, 2018b; 2019a; 2019b; 2019c; and 2019d). Field methods and sampling frequency for each sample type are presented below.

### 4.1.1 Water Quality Sampling

#### 4.1.1.1 In Situ Monitoring

*In situ* measurements of water temperature, DO, TDG, turbidity, and pH have been and continue to be collected using a multi-parameter Hydrolab Series 5 (MS5 or DS5) or YSI EXO sonde. For continuous monitoring the sondes 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 (see Section 4.2.1), 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 sonde 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 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.

Short-term *in situ* measurements of water temperature, DO, pH, specific conductance, and turbidity were conducted using YSI EXO sondes and Onset HOBO DO Data Loggers deployed at a depth of approximately 1-m (depending on water level), and data are logged at 30-minute intervals. Loggers were deployed for a period of two to three weeks before retrieval.

#### 4.1.1.2 Water Samples

Water sampling protocols for laboratory analysis were adapted from Ecology's SOP EAP034 (Ecology 2017). In reservoirs, samples for laboratory analysis of turbidity, TSS, FC, nutrients, phytoplankton, carbon, and alkalinity are taken at specified depths (per Table 4.1-1) with a Van Dorn horizontal water sampler. Prior to sample collection, the water sampler is rinsed with either local water 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, Washington), an Ecology accredited laboratory, within acceptable holding times.

At tributary and mainstem Skagit River sites, grab samples are collected at depths less than 1-m. Laboratory prepared bottles are submerged and capped in flowing water.

#### 4.1.1.3 Periphyton

Periphyton samples were collected per Ecology's SOP EAP111 (Ecology 2019e). Coarse sediment from the streambed was removed and placed in a plastic tray, where a known area of the top surface of one rock within each of eight transects was scrubbed with a firm-bristled brush using a circular motion. Filamentous algae and mosses were removed from the rocks by scraping with a knife. Scraped periphyton was rinsed from rocks and placed in sample bottles with Lugol's solution for laboratory analysis of ash free dry weight. Subsamples for analysis of chlorophyll *a* and pheophytin *a* were taken by removing approximately 10-milliliters (mL) of rinsate prior to the addition of Lugol's solution and filtered in the field immediately after sample collection. Filters were placed on dry ice and transferred along with ash free dry weight samples to EcoAnalysts, Inc. in Moscow, Idaho.

#### 4.1.1.4 Zooplankton

To characterize baseline zooplankton communities in Project reservoirs, three vertical plankton tows are completed with a round-top 64 micron (μ) mesh net and composited for analysis. Tow lengths depend on reservoir depth, but the target lengths are 50-m in Diablo Lake and 20-m in Gorge Lake for each vertical tow. Sample sites include Diablo Lake in the Main Basin and Gorge Lake near Gorge Dam. Reservoir zooplankton samples are collected by NPS.

Zooplankton samples were also collected downstream of Gorge Powerhouse using the same net and methods used for sampling benthic invertebrate drift (500 μ mesh, see below). The net was anchored and left in place for approximately 45 minutes. Samples were preserved with ethanol at the time of collection and transferred to EcoAnalysts, Inc. for identification.

### 4.1.2 Benthic and Drifting Macroinvertebrates

As explained in Section 2.0, the macroinvertebrate sampling program has been expanded substantially from what was outlined in the FERC-approved study plan. Sampling locations, methods, and frequencies are outlined in Table 4.1-2. Sampling underway includes kicknet sampling of BMI and invertebrate drift in reservoir tributaries and the Skagit River, benthic grab sampling using a PONAR dredge in reservoirs; and placement of rock baskets to assess BMI colonization rates in the varial zone of Ross Lake. BMI and drift sampling methods are outlined below for each of the above sample types.

#### 4.1.2.1 Kicknet Sampling

BMI samples are collected using procedures described in Ecology SOP EAP073 (Ecology 2019a), using a D-frame kicknet with a mesh size of 500 μ and an area of 1 foot (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 individuals that cling to the substrate, followed by disturbing the sediment with the toe of a boot to a depth of approximately 4 inches, for 30 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, Inc. for identification.

The number of sites within the Skagit River increased from seven locations in 2021 to 15 locations in 2022 to better characterize longitudinal patterns in BMI species composition and density and to extend the study area farther downstream, to the SR 9 bridge (PRM 23.1), adding two additional sites in the Sauk River, and adding five side channel locations; each side-channel sampling location is associated with a main channel sampling location.

The kicknet sampling procedures described above are followed for intensive kicknet sampling; however, instead of collecting eight samples over two bankfull widths, five samples are collected in the main channel along a transect extending laterally from the riverbank into the channel, and three samples are collected along the same transect in side channel habitat. Samples are distributed across one side of the river between the bank and the thalweg, as deep as safely accessible. Distance between each sample is dependent on the amount of sampleable area between the thalweg and shoreline; sample sites are typically 5-10-m apart. Each of the eight 1 $ft^2$ kicknet samples are kept separate for eight individual 1 $ft^2$ samples, i.e., they are not composited.

#### 4.1.2.2 Drift Sampling

Methods for stream drift sampling are based on those currently in use by USGS (Duda 2022). Wildco Model 3-15-C35 Drift nets (18 x 12 inch opening, 39-inch cod end with 500 μ mesh) are deployed in shallow riffles at each site; two replicate nets are placed next to each other. The nets are not fully submerged. Velocity is measured at the middle of each net mouth just prior to net retrieval, and submerged depth of the net is measured at the left side, middle, and right side of the net mouth. These measurements of net mouth area and velocity are used, along with total time of net deployment, to calculate the volume of water sampled during deployment, so that drifting biomass can be standardized as a density (i.e., mass of invertebrates per volume of water). Deployment times are approximately 30 minutes; actual times are recorded. After retrieval, nets are washed from the outside, and all drift items rinsed into a 500 μ sieve. Large pieces of debris are thoroughly rinsed with a squirt bottle of filtered water to wash affixed macroinvertebrates into the net and then discarded. Remaining drift contents are then placed into a sample bottle and preserved with ethanol. Samples are transferred to EcoAnalysts, Inc. in Moscow, Idaho, for taxonomic analysis. Blotted wet weights (grams [g]) for each invertebrate taxonomic order occurring in the preserved drift samples are measured to the nearest 0.0001g.

#### 4.1.2.3 Reservoir Benthic Sampling

Samples were collected from the lentic zone within Project reservoirs with a PONAR grab, following procedures described in U.S. Environmental Protection Agency (EPA 2016) and New York State Department of Environmental Conservation (NYSDEC 2021). Each sample was collected by gently lowering a PONAR sampler (Wildco Petite PONAR, 6 x 6 inch opening, 2.4 L sample volume) with its jaws in the open position until the sampler contacted with the reservoir bottom, which relaxed pressure on a spring-actuated bolt and set off the trigger to close the jaws, collecting a sediment sample. All PONAR samples were collected in replicate (i.e., two samples). Following collection, the sample was rinsed into a 500 μ sieve. Large pieces of debris were thoroughly rinsed with a squirt bottle to wash affixed BMI into the sieve and then discarded. Remaining sediment contents were then placed into a sample bottle and preserved with ethanol. Samples were delivered to EcoAnalysts, Inc. in Moscow, Idaho. As described for drift samples, blotted wet weights (g) for each invertebrate taxonomic order occurring in the preserved samples are measured to the nearest 0.0001g.

#### 4.1.2.4 Benthic Colonization Baskets

BMI samples were collected in the Ross Lake lentic zone by deploying colonization baskets on the reservoir bottom, following procedures described in Vermont DEC (2012) and Wooten et al. (2006). Wildco Artificial Substrate Baskets (6.5 inches diameter x 11 inches long, made of 1-inch square galvanized wire coated with PVC) were filled with commercially sourced, triple-washed, landscaping-grade “round rock,” a mixture of coarse gravel and small cobble 1-2 inches in diameter. One end of each basket was permanently fastened; the other was held closed with hinges and a swivel snap hook reinforced with cable ties. Each basket was rigged with a length of diamond braided polyester rope (3/8-inch diameter, Ravenox) sufficient to deploy the basket to the appropriate depth, and end-knotted with an Eva foam float providing 4.5 lbs of buoyancy (6.5 x 5.5 inches, KD-20, Lee Fisher). In an attempt to minimize loss of colonizing BMI during retrieval, each basket was surrounded by a mesh envelope (3 x 3 ft, 500 µ mesh). Envelope corners were affixed to a central metal ring on the polyester rope, such that the envelope pursed up to enclose the basket and contain the sample during retrieval. Colonization baskets were deployed when Ross Lake was at maximum water surface elevation in late June 2022 and retrieved in replicate at 5 weeks and 11 weeks post-deployment.

Upon retrieval, baskets and mesh envelopes were immediately transferred into double labeled heavy duty plastic bags, sealed with cable ties for transport from the reservoir to the field station. At the field station, each sample was then emptied into a clean, solid-bottom 5-gallon bucket for processing. Mesh envelopes and plastic bags were gently rinsed into the bucket and visually examined to ensure no BMI individuals remained. Water was added to the bucket and rocks were gently disturbed, scrubbed, and removed. The remaining sample was rinsed into a 500 µ sieve. Remaining sample contents were placed into a sample bottle and preserved with ethanol. Samples were delivered to EcoAnalysts, Inc. in Moscow, Idaho.

#### 4.1.2.5 Taxonomic Laboratory Analysis and Reporting

Delivery of BMI and drift samples to EcoAnalysts, Inc. in Moscow, Idaho, is staggered based on timing of sample collection and quantity available for transport.

At EcoAnalysts, Inc., macroinvertebrate samples are sifted through a 500 µ sieve and material caught is distributed into a Caton tray. This material is sorted by fraction of the tray’s contents through a dissecting microscope until a target count of 500 macroinvertebrates is reached or the entire sample is processed. Only individuals containing heads are removed from the sample. Invertebrates are identified to the lowest practical taxonomic level, typically genus or species for aquatic life-stages and family for terrestrial species. Individuals from each unique taxon are placed into a separate vial to create a synoptic reference collection for the samples. Remaining individuals are vouchered to order. Blotted wet weights (g) of preserved samples of each invertebrate taxonomic order, reported for drift and PONAR samples only, are measured to the nearest 0.0001 g.

Metrics provided by the taxonomic laboratory to help interpret macroinvertebrate results fall into two general categories: 1) indices that rank or score the samples based on established statistical relationships, e.g., sensitivity or tolerance of specific taxa to disturbance, such as organic enrichment or excess fine sediment; and 2) non statistically based taxa metrics. Assumptions associated with index values, or scores may or may not be met for a given sample or sampling location, in particular assumptions related to watershed size, flow, or stream wadability, and, therefore, index scores suggesting impacts, or lack thereof, could be misleading. An example of such an index is the Lower Puget Sound Index of Biotic Integrity (B-IBI), which was reported for BMI samples collected in 2021. However, the Puget Sound Benthos, a joint Ecology King County Study, found B-IBI scoring was not strongly correlated with human disturbance at the watershed or local scale in large rivers and so could not be applied meaningfully to such systems (King County 2015). For these reasons, a subset of only non-statistically based metrics are reported in this study report,[2] including the following:

- **Total abundance:** Total number of identifiable individuals in a sample. For replicated samples, reported total abundance is the average of the replicate pair.
- **Taxa richness**: Total number of identifiably distinct taxa in a sample. Taxa richness includes all the different invertebrates collected from a site, including members of the following taxonomic groups: mayflies, caddisflies, stoneflies, true flies, midges, clams, snails, and worms. For replicated samples, reported taxa richness represents the mean total taxa for the replicate pair.
- **Percent EPT composition**: Total taxa in the insect orders *Ephemeroptera* (mayfly), *Plecoptera* (stonefly), and *Trichoptera* (caddisfly). Percent EPT composition is the fraction of the sample composed of taxa within these three orders; most taxa in these orders are intolerant of sedimentation, unnatural flow variation, elevated temperature, and metals contamination. For replicated samples, percent EPT composition is the average for the replicate pair.
- **Percent functional group composition:** The functional group composition of the sample is reported as shown below. For replicated samples, reported percent functional group composition represents the mean of individual functional group percentages calculated for the replicate pair. Because certain replicates did not contain any macroinvertebrate individuals, there are cases in which aggregate functional group composition totals 0 percent (no individuals in either replicate) or 50 percent (no individuals in one replicate).
  - **Percent filterers:** The relative abundance of all individuals in a sample whose *primary* feeding mechanism is to filter suspended fine particulates, expressed as a percentage of the total number of individuals in the sample.
  - **Percent gatherers:** The relative abundance of all individuals in a sample whose *primary* feeding mechanism is to gather deposited fine particulates, expressed as a percentage of the total number of individuals in the sample.
  - **Percent predators:** The relative abundance of all individuals in a sample whose *primary* feeding mechanism is to pierce or engulf other invertebrates, expressed as a percentage of the total number of individuals in the sample.
  - **Percent scrapers:** The relative abundance of all individuals in a sample whose *primary* feeding strategy is to scrape attached periphyton and other particulates, expressed as a percentage of the total number of individuals in the sample.

[2] Results are reported as averages for replicate pairs for samples in Ross and Diablo lakes and their tributaries. Gorge Lake replicate pairs are reported individually, except for percent EPT composition and taxa richness for Stetattle Creek, which are averaged.

- **Percent shredders:** The relative abundance of all individuals in a sample whose *primary* feeding mechanism is to shred coarse particulate organic matter, expressed as a percentage of the total number of individuals in the sample.
- **Percent piercer-herbivore:** The relative abundance of all individuals in a sample whose *primary* feeding mechanism is to pierce vegetation (filamentous algae and other), expressed as a percentage of the total number of individuals in the sample.
- **Percent unclassified:** The relative abundance of all individuals in a sample whose *primary* feeding mechanism is unknown or unclassified, expressed as a percentage of the total number of individuals in the sample.

### 4.1.3 Ross Lake

#### 4.1.3.1 Water Quality

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 report, results are summarized through October 2022 (see Table 4.1-1 for an overview of the full sampling program, including the number of samples that remain to be collected). Turbidity was intended to be measured *in situ* using a digital water quality meter. However, starting with the July 2021 event, turbidity samples were sent for laboratory analysis to be analyzed concurrently with the TSS samples.

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 identified in Table 4.1-1, Figure 4.1-1, and on maps in Attachment A. FERC's SPD specified sampling at 1-m and 5-m depths adjacent to tributary mouths. However, given depths observed in the field, samples are collected at the mouths 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.

From June to September 2022, as part of the expanded water quality sampling program, grab samples were collected at the Ross Lake log boom (ROSS12) location at three depths representing the epilimnion, metalimnion, and hypolimnion and analyzed for nutrients, chlorophyll *a*, alkalinity, organic and inorganic carbon, and carbonaceous biochemical oxygen demand (CBOD). The depths for epilimnion, metalimnion, and hypolimnion grab samples were determined in the field based on temperature depth profiles measured in the field at the time of sampling (Table 4.1-3). Epilimnion samples targeted the top 5-m (except in May when the water column was not stratified—so the sample was collected roughly mid-depth of the epilimnion), metalimnion samples were obtained at approximately the mid-depth of the thermocline, and hypolimnion samples were collected within a few meters of the bottom. Similar depth profile sampling occurred in November 2022 and is occurring once during the winter of 2022-2023.

For the periods noted above, and as part of the expanded water quality sampling, grab samples collected for the analysis of the water quality parameters above were also collected at the international border (TRIB1) and the mouths of the following Ross Lake tributaries: Little Beaver Creek (TRIB3), Lightning Creek (TRIB4), Big Beaver Creek (TRIB8), and Ruby Creek (TRIB11).

**Table 4.1-3. Depths of epilimnion, metalimnion, and hypolimnion samples at Ross Lake log boom (ROSS12).**

| Date | Epilimnion Sample Depth (m) | Metalimnion Sample Depth (m) | Hypolimnion Sample Depth (m) |
|---|---|---|---|
| May 25, 2022 | 20 | 45 | 86 |
| Jun 30, 2022 | 5 | 32 | 100 |
| Jul 20, 2022 | 5 | 40 | 98 |
| Aug 17, 2022 | 5 | 13 | 48 |
| Sep 27, 2022 | 5 | 22 | 42 |

In addition to the locations described above, TSS and turbidity were 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, pp. 2, 3, and 5, respectively.

*In situ* field measurement protocols were adapted from Ecology's SOP EAP011 and EAP129 (Ecology 2019b, 2019c). *In situ* temperature, DO, and pH were measured using digital water quality meters (YSI EXO1 or equivalent). Each meter met the accuracy and precision requirements in the QAPP (City Light 2021). Probes were lowered to the desired depth, and values were recorded after 1 minute of stabilization. Prior to each event, the water quality meters were recalibrated using deionized water and standards for the corresponding field water quality parameter. After each event, a post-calibration check was performed to assess instrument drift. Pre- and post-calibration checks were performed either by the field crew or by the vendor who provided the equipment.

Bacterial 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 to FC samples, *Escherichia coli* (*E. coli)* samples were collected at Ross Lake Resort (ROSS8) during the August event and at all FC sites from the September 2021 event onwards 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 [Washington Administration Code (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 were collected approximately 15 centimeters (cm) below the water surface using a Van Dorn horizontal water sampler. To avoid contamination, clean gloves were used to handle all equipment, and the depth sampler was rinsed with isopropyl alcohol or ethanol and then rinsed with nearby site water prior to each sample. Samples were poured directly into sterile bottles with sodium thiosulfate to neutralize residual chlorine. Samples were immediately packed into coolers with ice and transported to Edge Analytical Laboratory in Burlington, WA for processing within 8 hours of collection.

Water quality data collected under the expanded sampling program allow for the characterization of the trophic status of Ross Lake. Nutrients and chlorophyll *a* data have been used to gauge trophic status and to provide reference values indicative of trophic conditions (Carlson 1977, Wetzel 2001). Nutrient and chlorophyll *a* data were compared to these values to provide a basis for an assessment of trophic status.

Locations of the monitoring sites are shown in Figure 4.1-1 and Attachment A.

#### 4.1.3.2 Benthic and Drifting Macroinvertebrates

Benthic sampling was conducted in Ross Lake between June 2022 and October 2022. As shown in Table 4.1-2, PONAR and benthic colonization basket sampling occurred at Hozomeen (HOZ), Desolation (DES), Pumpkin Mountain (PUM), and Ruby Arm (RUB). For a given sampling site, replicate samples were collected at each of three depth strata: the upper varial zone (10-20 ft depth at maximum surface elevation), the lower varial zone (50-60 ft depth at maximum surface elevation), and the permanently inundated zone (70-80 ft depth at maximum surface elevation). PONAR sampling was conducted at approximately six-week intervals. Colonization baskets were collected at five weeks and 11 weeks post-deployment.

Benthic kicknet and drift net sampling will occur in Ross Lake tributaries in May 2023.

### 4.1.4 Diablo Lake

#### 4.1.4.1 Water Quality

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 Powerhouse at the northwest corner of the boathouse near the base of Ross 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.[3] 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, Washington). Profiles and water samples are collected on a monthly basis at both sites and will continue through May 2023.

During fall, winter, and spring of 2021-2022, turbidity and TSS were measured along two 100-m transects in the Thunder Arm to characterize conditions when the reservoir is drawn down. The transect location identified in the RSP (DIABLO3) is upstream of the SR 20 Bridge, in the Colonial Creek Campground area. An additional transect, DIABLO6, was added for turbidity and TSS sampling in Diablo Lake downstream of the SR 20 Bridge to examine a possible erosional area

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

identified during a field visit. Transect sampling along DIABLO6 is completed using the same methodology and sampling interval as for DIABLO3. Sampling will occur again in winter and spring of 2023.

Per the RSP, samples for FC analysis were collected at two sites in Diablo Lake; DIABLO4 is located at the Thunder Creek confluence with Diablo Lake, upstream of the SR 20 Bridge, from the constructed 'peninsula' at Colonial Creek Campground; theDIABLO5 sample was collected at the dock of the Environmental Learning Center. Bacterial samples were collected monthly from June through September at these locations.

From June to September 2022, grab samples were collected at DIABLO2 at three depths representing the epilimnion, metalimnion, and hypolimnion and analyzed for nutrients, chlorophyll *a*, alkalinity, organic and inorganic carbon, and CBOD. This depth profile sampling also occurred in November 2022 and once during winter 2022-2023. As with the Ross Lake log boom location, the depths of epilimnion, metalimnion, and hypolimnion were determined based on a field temperature depth profile at the time of sampling (Table 4.1-4). Epilimnion samples targeted the top 5-m, metalimnion samples were obtained from approximately the mid-depth of the thermocline, and hypolimnion samples were collected within a few meters of the bottom. Locations of the monitoring sites are shown in Figure 4.1-1 and Attachment A.

**Table 4.1-4. Depths of epilimnion, metalimnion and hypolimnion samples at Diablo Dam Forebay (DIABLO2).**

| Date | Epilimnion Sample Depth (m) | Metalimnion Sample Depth (m) | Hypolimnion Sample Depth (m) |
|---|---|---|---|
| May 25, 2022 | 5 | 35 | 55 |
| Jun 30, 2022 | 5 | 22 | 57 |
| Jul 20, 2022 | 5 | 10 | 57 |
| Aug 17, 2022 | 5 | 13 | 54 |
| Sep 27, 2022 | 5 | 25 | 55 |

As noted for Ross Lake, nutrient and chlorophyll *a* data for Diablo Lake were compared to reference values (Carlson 1977, Wetzel 2001) to provide a basis for an assessment of trophic status.

#### 4.1.4.2 Benthic and Drifting Macroinvertebrates

Benthic and drift sampling were conducted in Diablo Lake and its tributary, Thunder Creek, between June 2022 and October 2022. As shown in Table 4.1-2, reservoir PONAR sampling occurred at Skagit Arm (SKA), Thunder Arm South (THS), Thunder Arm North (THN), and Main Basin (MNB) at approximately one-month intervals. The location of the Main Basin site was shifted downstream after the first two sampling events, from Buster Brown Bay to Main Basin. Due to the persistent difficulty of locating appropriate soft substrate at Skagit Arm, this site was only visited during the June and August sampling events and subsequently removed from the sampling schedule. Benthic kicknet and drift net sampling occurred in Thunder Creek on August 2 and August 30, 2022.

### 4.1.5 Gorge Lake

#### 4.1.5.1 Water Quality

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 sampling on Diablo Lake, vertical profiles of temperature, DO, and pH are collected monthly at 2-m intervals, and monthly grab samples are collected for turbidity and TSS at depths of 1 and 5-m at both sampling locations. Sampling for these parameters will continue through May 2023.

In addition to profiles and water sample collection, continuous monitoring of TDG began at GORGE3 and GORGE4 in September 2021. Hydrolab MS5s are placed within perforated PVC pipe and deployed at a depth of approximately 3-m. The sonde at GORGE3 is attached to a fixed location and logging depth varies with water surface elevation. The sonde at GORGE4 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 2021 per the RSP, TDG data collection at the two Gorge Lake locations was delayed due to supply chain issues at the sonde manufacturer.

Per the expanded water quality monitoring program, additional sampling has been conducted in Gorge Lake since May 2022. Grab samples were collected monthly from May to October, with two samples to be collected between October and May, 2023 (Table 4.1-1). Sampling includes *in situ* measurement of temperature, DO, pH, and specific conductance, and sample collection for turbidity, TSS, nutrients, chlorophyll *a*, phytoplankton, carbon, nutrients, and alkalinity at a depth of approximately 1-m. Grab samples are taken at the log boom upstream from the Gorge Dam forebay (GORGE7) and in Stetattle Creek (tributary to Gorge Lake; STET1) at the bridge at Gorge Campground. Locations of Gorge Lake water quality monitoring sites are shown in Figure 4.1-1 and Attachment A.

As noted for Ross and Diablo Lakes, nutrient and chlorophyll *a* data for Gorge Lake were compared to reference values (Carlson 1977, Wetzel 2001) to provide a basis for an assessment of trophic status.

#### 4.1.5.2 Benthic and Drifting Macroinvertebrates

As shown in Table 4.1-2, BMI sampling on Gorge Lake included PONAR sampling at Reflector Bar (GORGE1X), Stetattle Creek Confluence (GORGE6X), and West Zone (GORGE2X), as well as benthic and drifting macroinvertebrate sampling at Stetattle Creek. Samples from Stetattle Creek were collected using kicknets and drift nets.

### 4.1.6 Gorge Bypass Reach/Gorge Powerhouse

#### 4.1.6.1 Water Quality

Water quality monitoring within the Gorge bypass reach began in January 2021 at two locations; a third location was added in August 2021 when equipment was available from the manufacturer. BYPASS1 was located in the plunge pool immediately downstream of Gorge Dam, BYPASS2 was located in a pool approximately 1.5 miles upstream of Gorge Powerhouse, and BYPASS3 was located in a pool approximately 0.6 mile upstream of Gorge Powerhouse.

In addition to the three Gorge bypass reach sites, monitoring is being conducted immediately downstream of 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.

Water quality data were 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 sondes used in the Gorge bypass reach were deployed within perforated PVC pipes, anchored to boulders, and cabled to a second anchor point located approximately 10-20m 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 10-20m from the normal high-water mark. External 12 volt/10 amp lithium-ion batteries were connected to each of the sondes to augment their internal battery supply.

During fall 2021, sondes in the Gorge bypass reach were displaced during large spill events. Two of these units (BYPASS2 and BYPASS3) were dislodged and never recovered, and the unit in the plunge pool below Gorge Dam (BYPASS1) was irreparably damaged. To reduce safety risks to field staff and avoid additional loss of equipment and data, short-term deployments are now conducted in the Gorge bypass reach during baseflows and, opportunistically, during spill. Short-term deployments to collect baseline measurements occur at the BYPASS1 and BYPASS3 locations.

Preliminary results of monitoring found elevated TDG during a spill event in late June 2021 (see Section 5.2.5). To evaluate the downstream extent of elevated levels of TDG, monitoring at the Gorge bypass reach and Gorge Powerhouse locations is being augmented with measurement of TDG during spill events at locations downstream of Gorge Dam. These measurements are opportunistic and not all spill events are monitored. Measurements are being made via discrete, instantaneous samples or short-term programmed measurements with a Hydrolab sonde. Measurements of TDG are being made at up to four locations: (1) Gorge Dam access bridge, located just below the Gorge Dam plunge pool; (2) Gorge Powerhouse access bridge, which is located just above the mixing zone where waters from the Gorge bypass reach and Gorge Powerhouse merge; and (3) two locations in the Skagit River downstream of Gorge Powerhouse, (e.g., Ladder Creek Bridge, Trail of the Cedars Bridge). Preliminary data from spill events monitored in October 2021 and July 2022 under this modified protocol are presented in Section 5.

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 mile downstream of Gorge Dam. This unit collects barometric pressure data (mmHg [millimeters of mercury]) at 30-minute intervals. Pressure data from the Burlington Airport and a nearby sensor (operated by Northwest Hydraulic Consultants, Inc.) were used to fill a gap in coverage due to logger malfunction during the summer of 2022. Following correction for elevation, a sensitivity analysis was conducted to determine adequacy of the replacement barometric pressure data. The Onset sensor was replaced with a new unit (same make and model) and logging of barometric pressure will continue as long as TDG is monitored, currently planned to continue through May 2023.

Per the RSP, samples for laboratory measurements of TSS are collected at 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 when collected.

#### 4.1.6.2 Benthic and Drifting Macroinvertebrates

Benthic and drifting macroinvertebrates were sampled from May 2022 through October 2022 at roughly six-week intervals in the Gorge bypass reach above Gorge Powerhouse, downstream of Existing Feature 1, which is located approximately 10,000 ft downstream of Gorge Dam (Table 4.1-2 and see Attachment A).

### 4.1.7 Skagit and Sauk Rivers below Gorge Powerhouse

#### 4.1.7.1 Water Quality

Under the RSP, water temperature was monitored/sampled at six sites in the Skagit River downstream of Gorge Powerhouse and at one site in the lower Sauk River. Two additional main channel and four side channel locations have been added in the Skagit River under the expanded water quality monitoring program. In addition, in support of water quality model development, grab samples for nutrients and other analytes are being collected at multiple sites and continuous *in situ* monitoring of multiple parameters has been conducted at three sites in the lower river (Table 4.1-1).

Per the RSP, monitoring has been conducted in the Sauk River in addition to Skagit River mainstem sites. SAUK1 was to be deployed at RM 2.8; however, the river channel is braided at this location with variable shorelines. Therefore, the SAUK1 thermograph was deployed at RM 5.4 where conditions are stable and consistently wetted. This site continues to be monitored, and one main channel and one side channel location have been added in the Sauk River upstream of the confluence with the Suiattle River.

Onset temperature loggers were placed within protective PVC pipes and cabled to anchor points on the streambank at each location. All units are programmed to record water temperature at 30-minute intervals. Temperature measurement will continue through May 2023.

#### 4.1.7.2 Benthic and Drifting Macroinvertebrates

Kicknet and drift net sampling for macroinvertebrates is conducted in wadable 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). Six BMI sites were monitored once in August 2021. In 2022, with the exception of the intensive sites (see below), all 12 sites were sampled at approximately six-week intervals from May through October.

Intensive BMI sampling is conducted at paired sites in the Skagit River (SKAGIT4, regulated) at PRM 75.6 and the Sauk River (SAUK2, unregulated), just upstream of the confluence with the Suiattle River. The paired sites were selected to be as similar as possible to each other in terms of elevation and channel characteristics. At each intensive sampling site, BMI samples are collected with a kicknet at intervals along a transect that runs from the thalweg at the maximum wadable depth to the shoreline, through the side channel. Five kicknet samples were collected along the transect in the main channel, and another three samples were collected along this transect in the side channel. Sampling at these intensive transect sites was conducted every two weeks from July-October 2022 and every four weeks from November-December 2022 and will be conducted from March-June 2023. Data from the two intensive sampling sites will be compared (Skagit versus Sauk rivers) in an attempt to discern whether there are apparent effects of the Project on the invertebrate community at the Skagit River (regulated) site.

Thermographs have been deployed to continuously monitor temperature at each of the intensive BMI sampling sites (SAUK2 and SKAGIT4). In addition, at the sampling site in the Sauk River, nutrient data (grab samples) are being collected quarterly to allow for a comparison of conditions before and after the influx of marine-derived nutrients from spawned-out salmon and steelhead carcasses.

## 4.2 Quality Assurance/Quality Control

A component of the RSP is the 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 study are accurate, usable, and repeatable. 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; 2018b; 2019a; 2019b; and 2019c). Specific methods for *in situ* and grab sampling are detailed below.

#### 4.2.1.1 *In situ* Sampling

**Multiparameter Sondes**

Hydrolab MS5s and DS5s and YSI EXO1 sondes are being used for continuous water quality monitoring at sites identified in Table 4.1-1. 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 sonde manufacturer, following published procedures and using approved calibration standards.

As recommended in Ecology SOP EAP129 (Ecology 2019c), mid-deployment field data quality checks are completed during sonde servicing, approximately once every four weeks. These checks include running performance tests with a newly calibrated sonde at each deployment site. Both the newly calibrated and deployed sondes 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 | 0.3 units |
| 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 2006).

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). 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 performance 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). TDG sensors have been recalibrated or membranes have been replaced during each visit for sonde maintenance/downloading, regardless of results of mid-deployment checks.

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 12 locations in the Skagit River downstream of Gorge Powerhouse and at three locations 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 collected in the field for parameters specified in the RSP, (i.e., TSS, turbidity, and FC), and for the broader suite of analytes beginning in May 2022, are sent to Edge Analytical in Burlington, WA (water chemistry and to EcoAnalysts, Inc. in Moscow, Idaho (phytoplankton, chlorophyll *a*, and periphyton). 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. 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 event to assess field variability or potential contamination due to sample collection or laboratory processing. If a sampling event includes multiple geographic areas (such as turbidity sampling at both Ross and Diablo lakes), only one duplicate sample is collected and the duplicate results apply to both geographic areas. 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. 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.

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

### 4.2.2 Benthic and Drifting Macroinvertebrate Samples

Protocols for reservoir tributary kicknet sampling and all drift and PONAR sampling require duplicates at each sampling location and event. For lower Skagit River kick samples, a field duplicate is collected at one site per sampling event or a minimum of 10 percent of samples collected, exclusive of intensive samples (described in Section 4.1.7). Relative Standard Deviation for duplicate samples is reported for metrics described in Section 4.1.2 (total abundance, taxa richness, percent EPT composition). Laboratory quality assurance for invertebrates, chlorophyll *a*, phytoplankton, periphyton, and zooplankton samples is conducted by EcoAnalysts, Inc. in Moscow, Idaho.

### 4.2.3 Processing of Continuous Data

Consistent with Ecology SOP EAP130 (Ecology 2019d), the first step in reviewing a Hydrolab or YSI sonde 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 is measured in the field, and percent DO saturation may either be measured or calculated (Oregon Department of Environmental Quality 2022).

Per 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 are of 90 percent or greater completeness for field and laboratory analyses. As described in the QAPP, data completeness is expressed as a percentage and is 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, the half-hourly observations reported in this study report were 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; qualified data included in processed data |
| Rejected | Data invalid (outliers, equilibration, exposure); removed from processed data |

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

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 collected prior to relicensing: tributary data, including those to the Skagit River and Project reservoirs, and data pertaining to Ross, Diablo, and Gorge lakes, covering 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 City Light will prepare a more comprehensive analysis of existing data, which was included as Attachment D to the WQ Monitoring Study Interim Study Report filed with FERC in March 2022 (City Light 2022a). A portion of existing data (gathered outside of relicensing) for Ross, Diablo, and Gorge lakes is discussed in Section 5.1, along with results of this study, to thoroughly describe water quality in the Project area. Sources for these data include sampling completed by the North Coast and Cascades Inventory & Monitoring Network (NCCN) and City Light outside of relicensing (Table 4.3-1).

**Table 4.3-1. Data collected outside of relicensing presented in this report.**

| Location | Entity | Parameter | Sampling Interval | Years of Data | Figure Number |
|---|---|---|---|---|---|
| **Ross Lake** | | | | | |
| 26-Mile Bridge | City Light | Temperature | Continuous | 2001-2019 | Figure 5.1-1 |
| Swing Bridge | City Light | Temperature | Continuous | 2002-2019 | Figure 5.1-1 |
| Klesilkwa River | City Light | Temperature | Continuous | 2001-2019 | Figure 5.1-1 |
| Sumallo River | City Light | Temperature | Continuous | 2003-2018 | Figure 5.1-1 |
| Little Beaver | NCCN | Temperature | Continuous, 3 depths | 2017-2018 | Figure 5.1-2 |
| Skymo | NCCN | Temperature | Continuous, 3 depths | 2017-2018 | Figure 5.1-3 |
| Pumpkin Mountain | NCCN | Temperature | Continuous, 3 depths | 2017-2018 | Figure 5.1-4 |
| Ross Lake Logboom | City Light | Temperature | Continuous, 10 depths | 2001-2019 | Figure 5.1-5 |
| Lightning Creek | City Light | Temperature | Continuous | 2000-2017 | Figure 5.1-7 |
| Hozomeen Creek | City Light | Temperature | Continuous | 2019-2020 | Figure 5.1-7 |
| Big Beaver Creek | City Light | Temperature | Continuous | 2000-2020 | Figure 5.1-7 |
| Little Beaver Creek | City Light | Temperature | Continuous | 2001-2019 | Figure 5.1-7 |
| Devil's Creek | City Light | Temperature | Continuous | 2000-2002 | Figure 5.1-7 |
| Ruby Creek | City Light | Temperature | Continuous | 2000-2018 | Figure 5.1-7 |
| Little Beaver | NCCN | Zooplankton | Monthly, May – November | 2015-2018 | Figure 5.1-17 |
| Skymo | NCCN | Zooplankton | Monthly, May – November | 2015-2018 | Figure 5.1-17 |
| Pumpkin Mountain | NCCN | Zooplankton | Monthly, May – November | 2015-2020 | Figure 5.1-17 |
| **Diablo Lake** | | | | | |
| Diablo Lake Log Boom | City Light | Temperature | Continuous, 9 depths | 2014-2019 | Figure 5.1-26 |
| McAllister Creek | City Light | Temperature | Continuous | 2014-2017 | Figure 5.1-27 |
| Fisher Creek | City Light | Temperature | Continuous | 2014-2017 | Figure 5.1-27 |
| West Fork Creek | City Light | Temperature | Continuous | 2014-2017 | Figure 5.1-27 |
| **Gorge Lake** | | | | | |
| Gorge Lake Log Boom | City Light | Temperature | Continuous, 8 depths | 2014-2019 | Figure 5.1-53 |
| Stetattle Creek | City Light | Temperature | Continuous | 2005-2019 | Figure 5.1-54 |

# 5.0 RESULTS

This section updates the WQ Monitoring Study Interim Study Report, filed with FERC in March 2022 (City Light 2022a), with results reported from both the water quality and taxonomic laboratories through early fall 2022. Data collection is ongoing and will extend through May 2023 for most variables; including benthic and drifting macroinvertebrates (see Tables 4.1-1, 4.1-2). Results reported in this section represent roughly 70 percent of the planned monitoring program. As noted in Section 2.0, fieldwork since May 2022 has reflected both the scope of the FERC-approved study plan and additional water quality and BMI/drift monitoring under the expanded program.

## 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, the information presented extends from June 2021 through September 2022. 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 4.1-1).

In addition to data collected during relicensing, this section includes a summary of existing temperature data for Ross, Diablo, and Gorge Lakes; as well as zooplankton data for Ross Lake, which has a more extensive period of record and data set than either Diablo or Gorge lakes.

### 5.1.1 Ross Lake

#### 5.1.1.1 Temperature

Continuously measured temperatures in the Skagit River and two of its tributaries upstream of Ross Lake (various measurement periods from 2001-2019, data collected by City Light outside of relicensing) are shown in Figure 5.1-1 (data for other tributaries are presented subsequently). Monthly average temperatures in the Klesilkwa River ranged from approximately 2°C to 12°C. Other Skagit River sites shown in Figure 5.1-1 exhibited less variability. Monthly averages calculated for individual years at the Swing Bridge location, about 0.5 mile upstream of the northern extent of Ross Lake, varied over a range of approximately 2°C, indicating moderate interannual variability in Skagit River temperatures entering Ross Lake.

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 fall. Vertical temperature profiles measured by NCCN outside of relicensing from 2017-2018 at the Little Beaver (48.936547, -121.07666), Skymo (48.86725, -121.033389), and Pumpkin Mountain (48.787917, -121.051278) sampling locations in Ross Lake, and profiles measured by City Light outside of relicensing at the log boom in the Ross Dam forebay (48.737218, -121.054392), are shown in Figures 5.1-2 through 5.1-5. At Little Beaver, surface temperatures increased from 15°C in May to 22°C in August and then decreased to 7°C in December (Figure 5.1-2). A difference in

4 Results of data collected in Ross Lake near the U.S.-Canada border by the USGS, Washington Water Science Center were provided in Attachment D to the WQ Monitoring Study Interim Study Report filed with FERC in March 2022 (City Light 2022a).

temperature between the "surface" and "middle" depths existed in spring but nearly disappeared by September. 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.

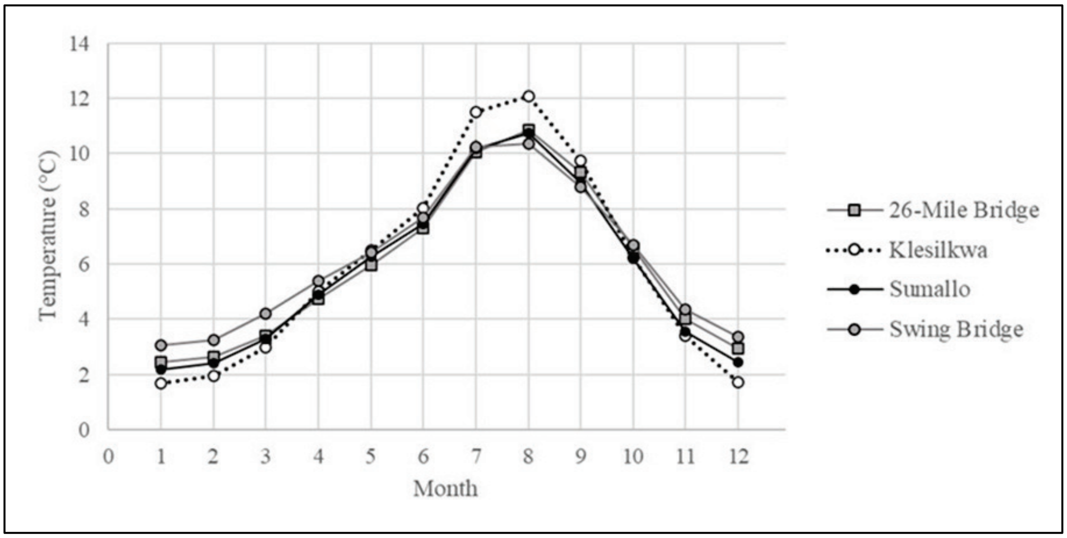



**Figure 5.1-1. Monthly averages of continuous temperature data measured at select Skagit River locations (26-Mile Bridge [2001-2019] and Swing Bridge [2002-2019]) and tributaries (the Klesilkwa [2001-2019] and Sumallo rivers [2003-2018]) upstream of Ross Lake. Source: City Light data collected outside of relicensing.**

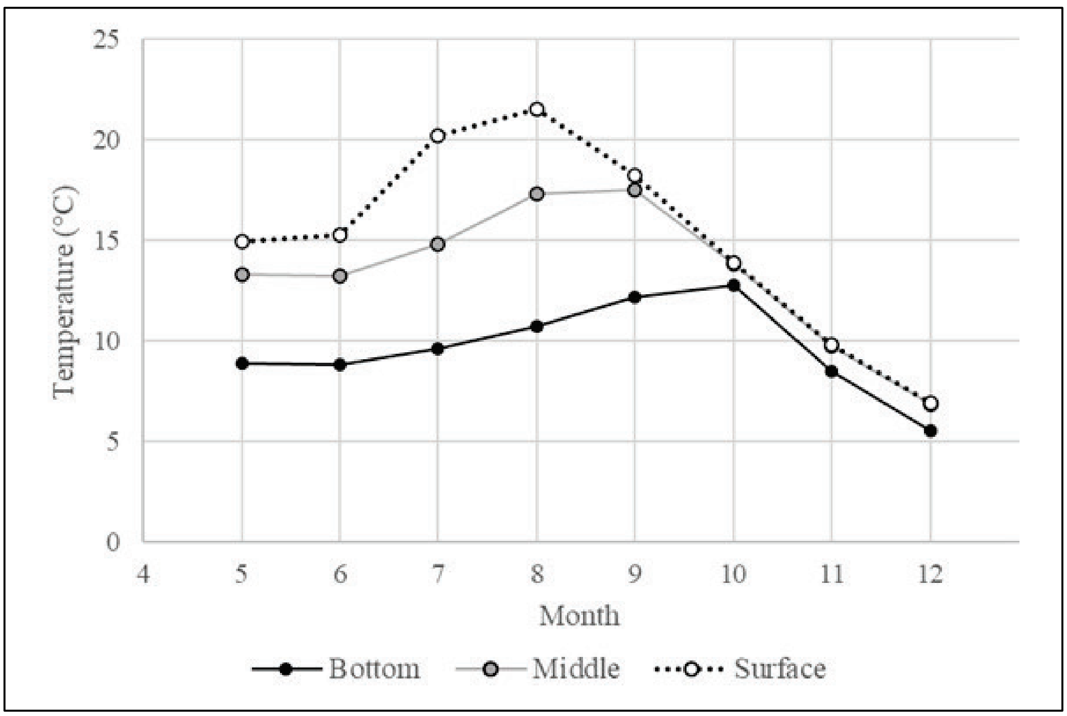



**Figure 5.1-2. Monthly average water temperature at surface, middle, and bottom depths at the Little Beaver monitoring location in Ross Lake (2017-2018). Source: Data collected by NCCN outside of relicensing.**

The temporal pattern at Skymo resembled that of Little Beaver, although 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 through December were close to those at Little Beaver.

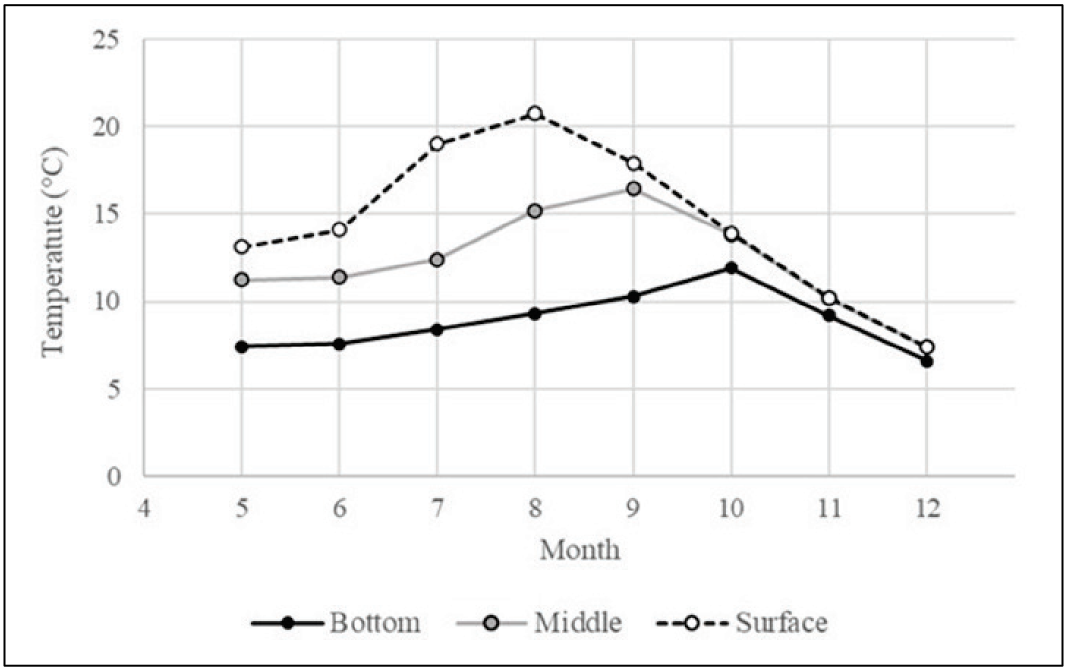



**Figure 5.1-3. Monthly average water temperature at surface, middle, and bottom depths at the Skymo monitoring location in Ross Lake (2017-2018). Source: Data collected by NCCN outside of relicensing.**

At Pumpkin Mountain, the monthly pattern of surface water temperatures (Figure 5.1-4) was similar to and slightly cooler than that of Little Beaver upstream. Middle depth temperatures were slower to rise during summer, because the "middle" depth at Pumpkin Mountain is deeper than at upstream sites. The greater depth at Pumpkin Mountain likely accounts for the nearly constant bottom water temperatures throughout the year.

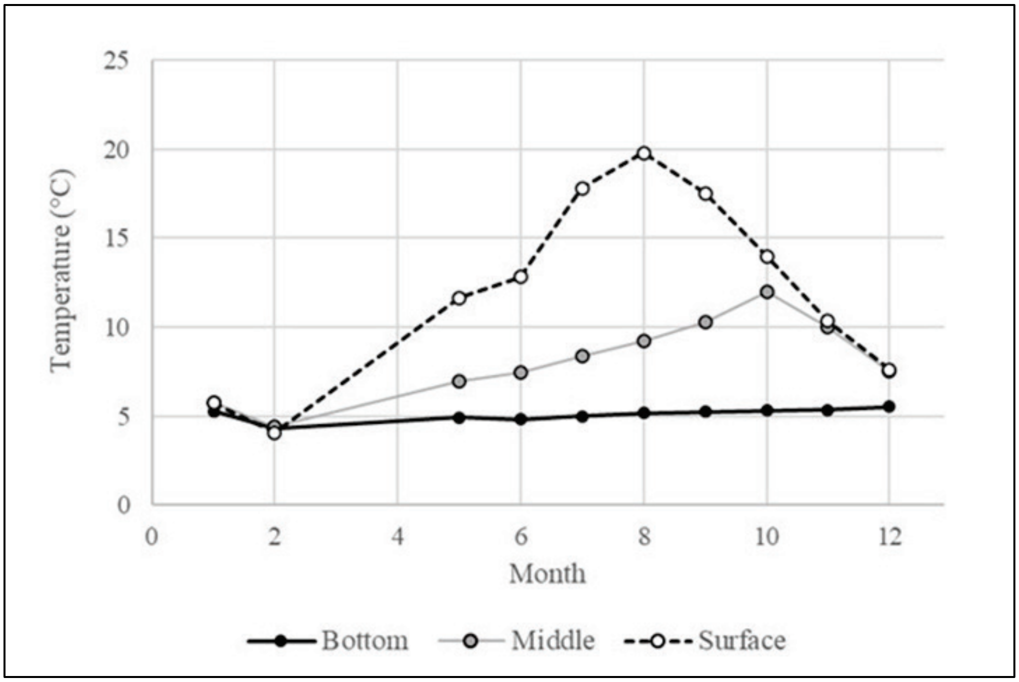



**Figure 5.1-4. Monthly average water temperature at surface, middle, and bottom depths at the Pumpkin Mountain monitoring location in Ross Lake (2017-2018). Source: Data collected by NCCN outside of relicensing.**

At the log boom in Ross Dam forebay, where monitoring occurred over a larger number of smaller depth increments (and over a greater number of years, 2001-2019),[5] monthly average surface temperatures ranged from slightly below 4°C to 18.5°C (Figure 5.1-5). Temperatures at 200 ft increased from 4°C to almost 8°C by November. Monthly average temperatures at the log boom show that stratification begins in April and persists through August, and vertical mixing of the water column occurs from fall through early winter until the water column is isothermal to a depth of 200 ft by January. Depth profiles of temperature were also collected at a finer vertical resolution at the Ross Lake log boom (ROSS12) in 2022 as part of the extended monitoring to support CE-QUAL-W2 model validation. The temperature depth profile showed a similar pattern as in previous sampling with peak stratification in August that begins to break up in September (Figure 5.1-6).

Surface temperatures in Ross Lake were significantly higher than those measured in the Skagit River at Swing Bridge. Surface water temperatures were slightly warmer at Little Beaver (northernmost) than the Skymo and Pumpkin Mountain (southernmost) locations. Maximum reservoir surface temperatures exceeded 20°C, whereas maximum river temperatures reached only about 12°C, indicating that warming of Ross Lake is due to solar radiation, not river inflows. When Ross Lake was stratified, mechanical mixing of the surface layer due to wind appears to be more pronounced at the upstream locations than near Ross Dam, where a mixed surface layer was not observed (see the relative thermal resistance to mixing plots in Appendix 5 to Attachment D of the WQ Monitoring Study Interim Study Report, City Light 2022a).

5 Continuous temperature monitoring along depth profiles at the Ross Lake log boom (ROSS12) is ongoing. Data is collected by City Light outside of relicensing.

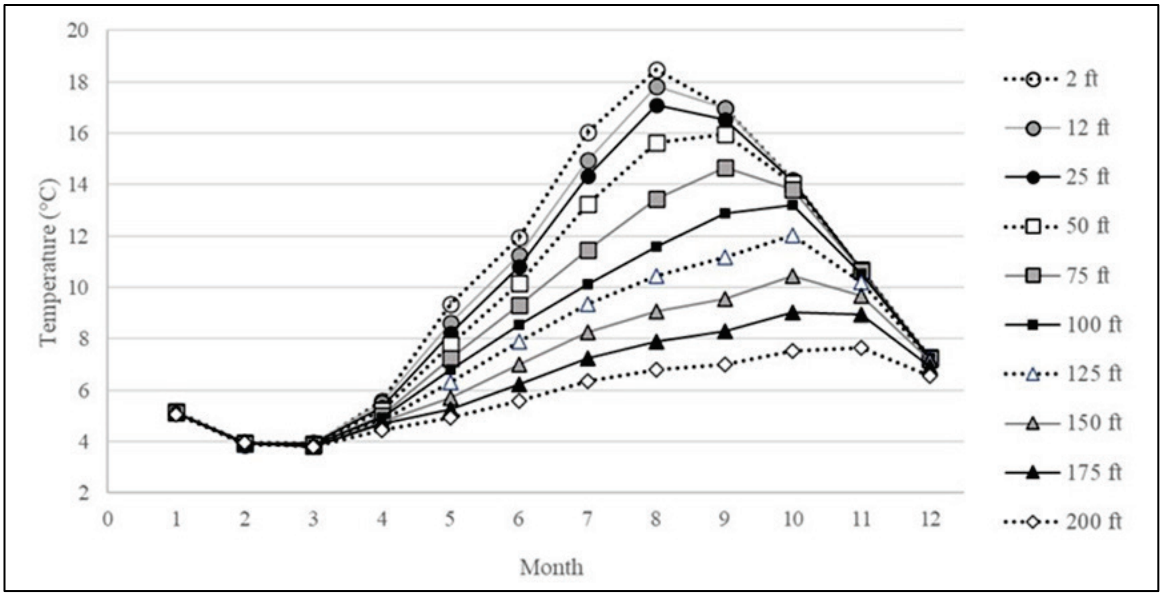



**Figure 5.1-5. Monthly average water temperature at 10 depths at the log boom monitoring location in Ross Lake (2001-2019). Source: City Light data collected outside of relicensing.**

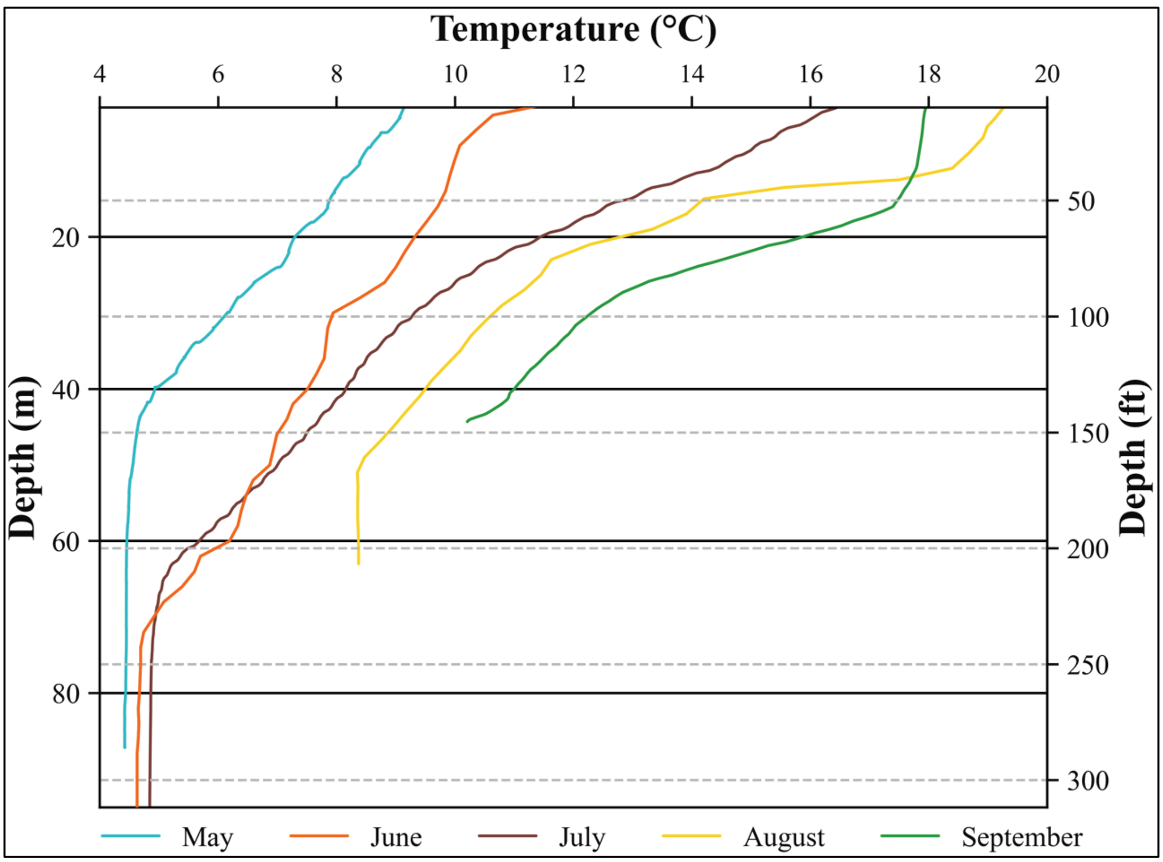



**Figure 5.1-6. Vertical profile of water temperature at the Ross Lake log boom (ROSS12) (2022).**

Monthly average temperatures in select tributaries (other than the upper Skagit River, which is discussed above) to Ross Lake[6] (various recording periods from 2000-2020) (Figure 5.1-7) ranged from less than 2°C (Devil's Creek in February) to nearly 12°C (Ruby Creek in August). 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. Little Beaver Creek, Hozomeen Creek, and Big Beaver Creek had the coolest summer temperatures, peaking at less than 10°C in August during the measurement periods. The monthly temperature patterns in summer of 2022 show the tributary trends in 2022 are comparable to the historical data (Figure 5.1-8).

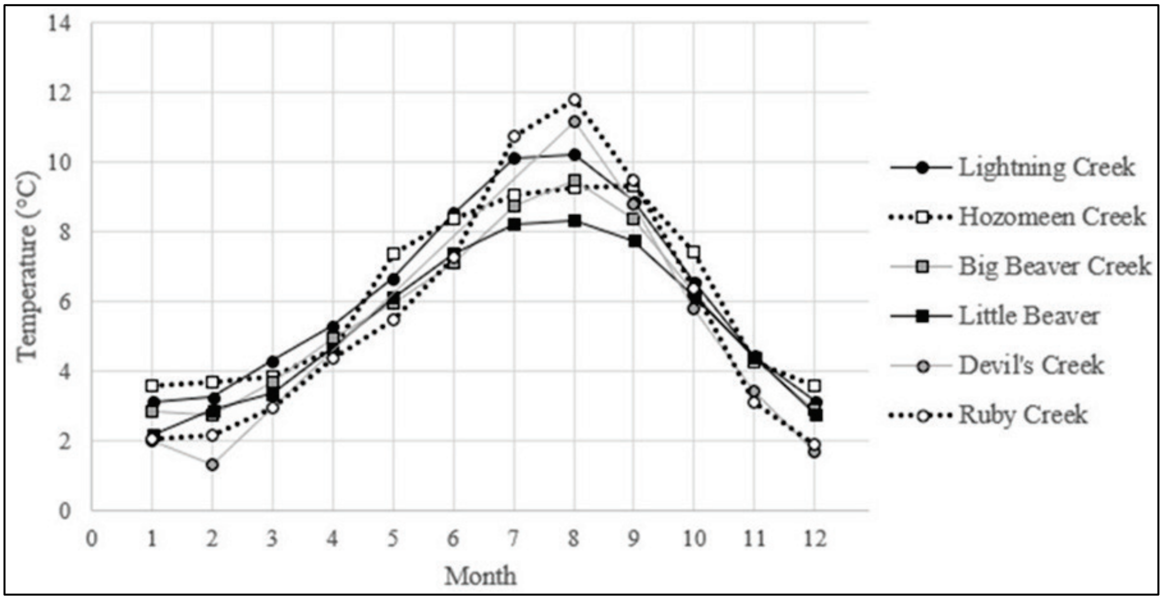



**Figure 5.1-7. Monthly averages of continuous temperatures measured in select tributaries to Ross Lake: Lightning Creek (2000-2017), Hozomeen Creek (2019-2020), Big Beaver Creek (2000-2020), Little Beaver Creek (2001-2019), Devil's Creek (2000-2002), and Ruby Creek (2000-2018). Source: City Light data collected outside of relicensing.**

6 Tributaries are monitored at consistent locations over time by City Light outside of relicensing. See WQ Monitoring Interim Study Report, Attachment D, (City Light 2022a) for maps and coordinates of sampling locations.

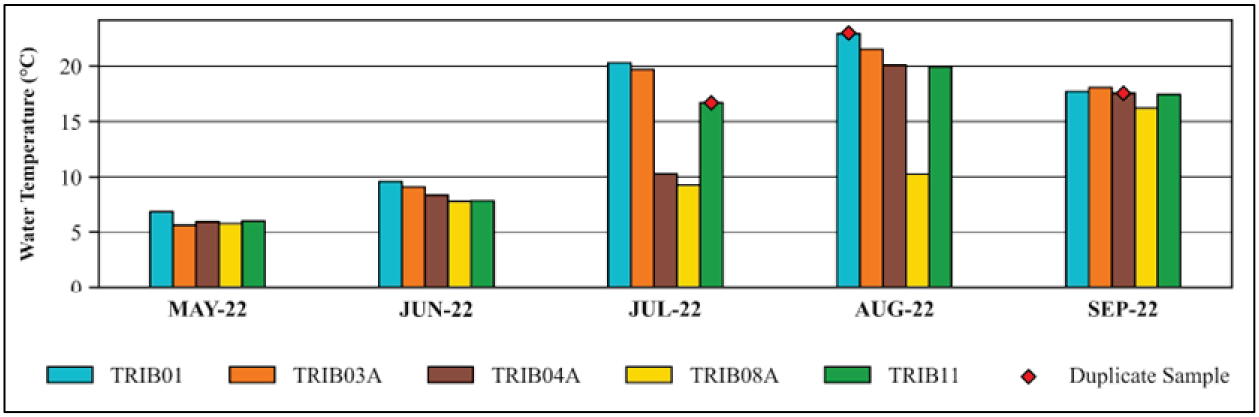



**Figure 5.1-8. Monthly temperatures at the International Border (TRIB01), Little Beaver Creek (TRIB03), Lightning Creek (TRIB04), Big Beaver Creek (TRIB08) and Ruby Creek (TRIB11) (2022).**

#### 5.1.1.2 Dissolved Oxygen, pH, and Specific Conductance

Measurements of DO, specific conductance, and pH in tributary inflows are shown in Figure 5.1-9. DO patterns show a seasonal cycle of cooler, DO rich waters in late spring and early summer that progressively warm in mid-summer with concomitantly lower DO levels. DO remained at or near saturation in spring and summer and was seldom supersaturated, indicating low primary production, which is consistent with observations of low chlorophyll *a* and nutrients (discussed below). This is also evident in the relatively consistent pH levels.

Depth profile measurements in the Ross Dam forebay (ROSS12) are shown in Figure 5.1-10. Equipment malfunction prevented the measurement of pH, DO, and specific conductance along depth profiles in June and August; however, point measurements of these parameters were taken at three depths using a second probe in August. August and September events were conducted off the thalweg (because the log boom, which was used to anchor the boat for the sampling, drifted off the thalweg) and therefore sampling during these months did not extend to the same depth as it did during May-July, when the log boom was closer to the thalweg.

The depth profiles and the point measurements show that DO levels remained high throughout the water column even under stratified conditions. Similarly, fluctuations in pH over depth were small, except in September when pH was lower near the sediment-water interface. The DO levels in the hypolimnion show that sediment oxygen demand is not high enough to result in hypoxic or anoxic conditions in the reservoir's hypolimnion, further supportive of an oligotrophic condition where the hypolimnetic oxygen demand is typically low.

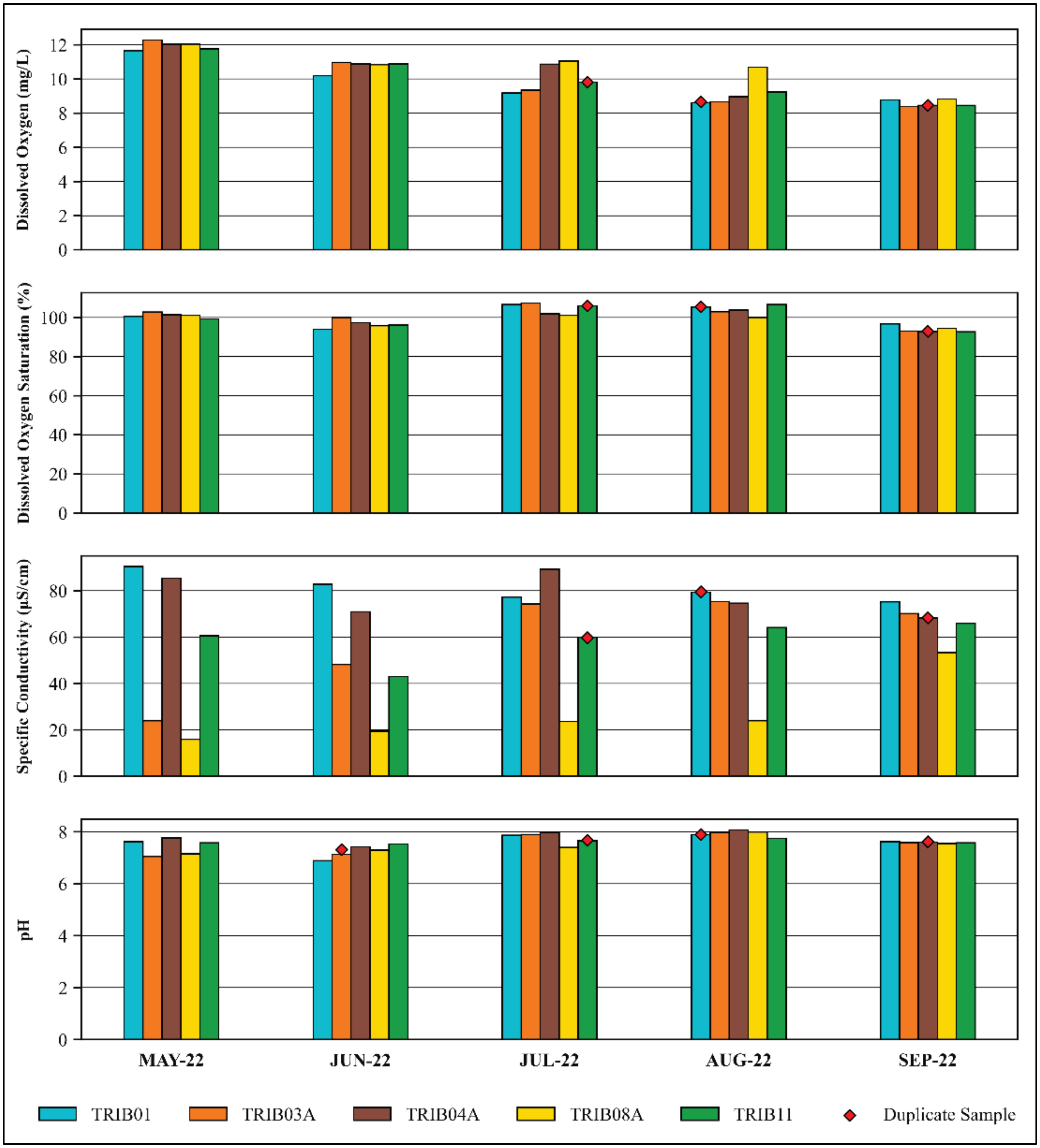



**Figure 5.1-9.** **Monthly measurements of DO, specific conductance, and pH at the International Border (TRIB01), Little Beaver Creek (TRIB03), Lightning Creek (TRIB04), Big Beaver Creek (TRIB08) and Ruby Creek (TRIB11) (2022).**

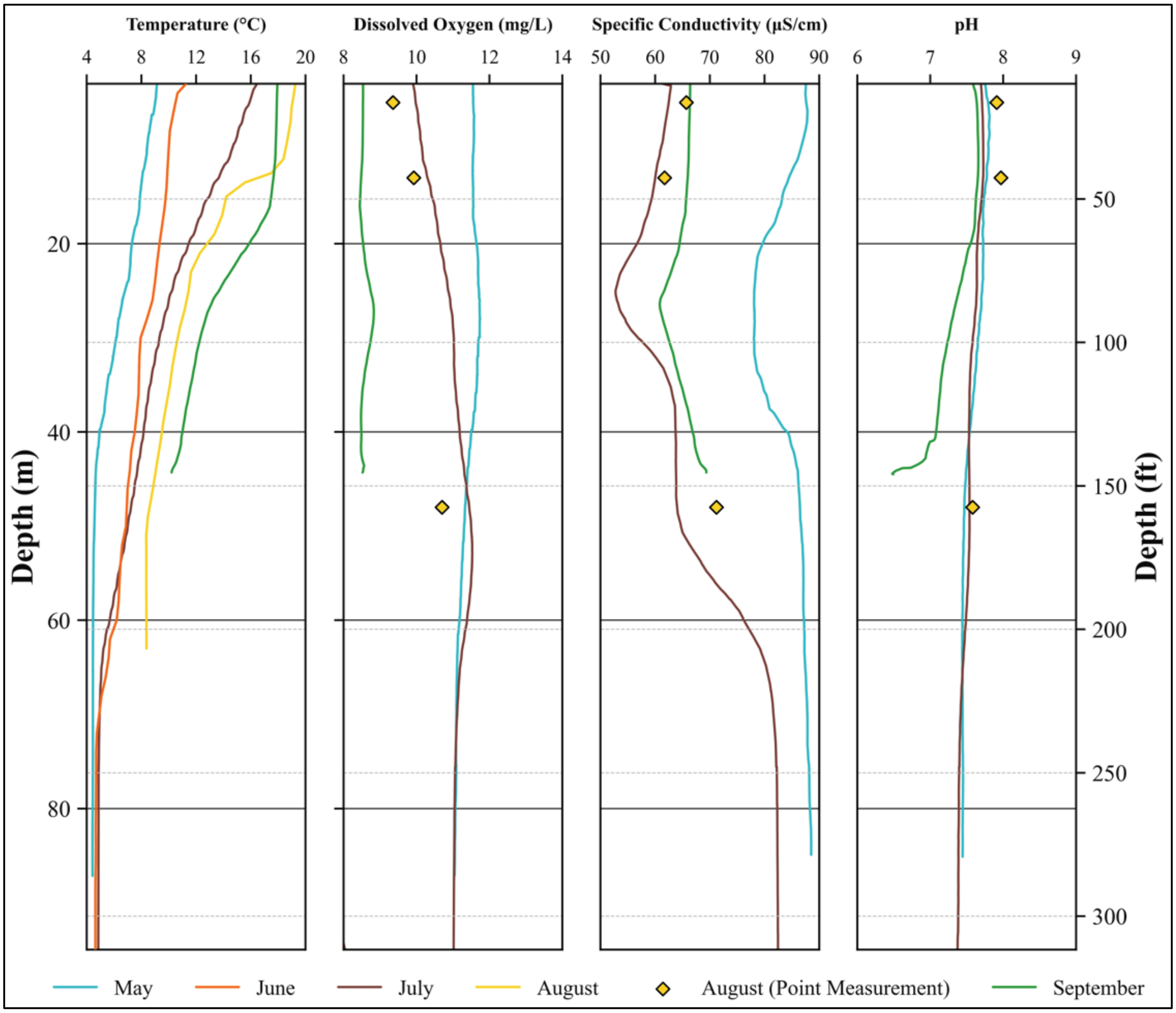



**Figure 5.1-10. Vertical profiles of temperature, DO, specific conductance, and pH at the Ross Lake log boom (ROSS12) (2022).**

### 5.1.1.3 Turbidity and Total Suspended Solids

**Monthly Sampling in Ross Lake**

Monthly sampling of turbidity and TSS commenced in June 2021 and will continue through May 2023. Field safety conditions precluded collection of samples in December 2021, January 2022 and April 2022. Results through October 2022 are presented in this section. Table 5.1-1 shows the measured turbidity and TSS at the three Ross Lake monitoring locations. As noted in Section 4.1.3.1, laboratory measurements of turbidity started in July 2021 and have been used in lieu of field measurements since then. In general, when paired *in situ* and laboratory measurements were available, the laboratory measurements were slightly higher and therefore provided a more conservative estimate of turbidity. Therefore, the laboratory measurements are reported in Table 5.1-1 (except for June 2021 when paired laboratory measurement was not conducted).

Turbidity and TSS levels in Ross Lake were generally low in the summer months of both years, with most measurements either below or close to the practical quantitation limits[7] (PQL) (Table 5.1-1). The highest turbidity and TSS levels were measured at the end of November 2021 at ROSS1 (Pumpkin Mountain) at both 1-m and 5-m depths, reflecting the runoff event from precipitation in late November of 2021. Turbidity levels during the November 2021 flood increased progressively from upstream (ROSS3 – Little Beaver) to downstream (ROSS1 – Pumpkin Mountain) reflecting additional turbidity from tributary inflows throughout Ross Lake (see also discussion on tributary turbidity below). Moderately higher levels of TSS and turbidity were also observed during spring snowmelt conditions from March – June 2022, but these levels were not appreciably above the quantitation limit. In most of the sampling events, and over both years, the differences in turbidity and TSS levels between the 1-m and 5-m samples were not appreciable, which indicates turbidity is relatively consistent over depth (and consistently low). These observations of low turbidity and TSS agree well with the relatively high Secchi depth measurements reported historically for Ross Lake (Secchi depth range of 6.5-11.2m in the mid-1980s at mid-reservoir near Lightning Creek; Funk et al. 1987).

**Turbidity and Total Suspended Solids Depth Profiles at the Ross Lake Log Boom**

The turbidity and TSS levels within Ross Lake log boom (ROSS12) are shown in Table 5.1-2. Turbidity and TSS levels were low throughout the year except for a minor spike in June 2022 in the metalimnion sample. The higher turbidity and TSS level are likely a result of tributary inflow during snowmelt, particularly inflows from Ruby Creek (TRIB11) (see Tables 5.1-4 and 5.1-5, and subsequent discussion on tributary turbidity and TSS). Surface temperatures at ROSS12 are warmer in June (Figure 5.1-6) relative to the cooler tributary inflows (see Figure 5.1-8). This would have caused to tributaries to plunge into the metalimnion, bringing along any associated solids and nutrients.

[7] The TSS practical quantitation limit (PQL) for samples through May 2022 are reported at 2 mg/L by the laboratory but decreased to 1 mg/L thereafter. There was no change in the analytical method or the laboratory, but the laboratory started processing a larger sample volume that enabled a lower reporting method.

**Table 5.1-1. Monthly turbidity and TSS sampling results for Pumpkin (ROSS1), Skymo (ROSS2), and Little Beaver (ROSS3) (2021 and 2022).**

| Date | Pumpkin (ROSS1) | | | | Skymo (ROSS2) | | | | Little Beaver (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 |
| 6/29/2021 | 0 (0) | 0 | ND (ND) | ND | 0 | 0 | ND | ND | 0 | 0 | ND | ND |
| 7/26/2021 | 0.4 | 0.48 | ND | ND | 0.59 (0.42) | 0.66 | ND (ND) | ND | 0.31 | 0.17 | ND | ND |
| 8/17/2021 | 0.39 | 0.41 | ND | ND | 0.32 | 0.43 | ND | 2 | 0.25 (0.30) | 0.22 | ND (ND) | 3 |
| 9/14/2021 | 0.94 (0.78) | 1.1 | ND (ND) | ND | 0.94 | 0.86 | ND | ND | 0.73 | 1.1 | ND | ND |
| 10/28/2021 | 0.46 | 0.35 | ND | ND | 0.35 (0.46) | 0.48 | ND (ND) | ND | 0.5 | 0.33 | ND | ND |
| 11/30/2021 | 13 | 13 | 4 | 4 | 10 | 10 | 3 | 3 | 6.7 | 6.5 | 2 | 2 |
| 2/24/2022 | 4.1 | 4.3 | ND | ND | 3 | 3.3 | ND | ND | 2.1 (2.1) | 2.2 | ND (ND) | ND |
| 3/16/2022 | 2.5 | 2.5 | ND | ND | 2.0 (2.1) | 1.8 | ND (2) | ND | 3.7 | 4 | 3 | 4 |
| 5/11/2022 | 1 | 1.1 | ND | ND | 1.6 (1.7) | 2.1 | 2.0 (2) | 2 | 3 | 3.5 | 3 | 2 |
| 6/22/2022 | 3 | 3 | 3 | 2.5 | 2.2 (2.1) | 2.1 | 2.0 (2) | 3 | 1.7 | 1.5 | 4 | ND |
| 7/19/2022 | 0.4 | 0.38 | ND | ND | 0.23 | 0.26 | ND | ND | 0.29 (0.26) | 0.39 | ND (ND) | ND |
| 8/17/2022 | 0.21 | 0.52 | 1 | 1 | 0.2 (0.12) | 0.16 | ND (ND) | 1 | 0.18 | 0.14 | ND | ND |
| 9/28/2022 | 0.15 | 0.16 | ND | 1 | 0.14 | 0.15 | ND | ND | 0.1 (0.14) | 0.17 | ND (1) | ND |
| 10/25/2022 | 0.54 | 0.33 | ND | 2 | 0.31 | 0.35 | ND | ND | 0.31 (0.42) | 0.37 | ND (ND) | ND |

Notes: Sampling started in June 2021. Winter/field safety conditions precluded sample collection in December 2021, January 2022, and April 2022.
Samples measured below the PQL are reported as ND. PQL is 2 mg/L through May 2022, and 1 mg/L thereafter for TSS, and 0.1 NTU for turbidity.
Field duplicate results are shown in parenthesis.
June 2021 turbidity data are from *in situ* measurements, while turbidity from other months is based on laboratory measurements.

**Table 5.1-2. Turbidity and TSS sampling results at the log boom of Ross Lake Forebay (ROSS12) (May–September 2022).**

| Date | Epilimnion | | Metalimnion | | Hypolimnion | |
|---|---|---|---|---|---|---|
| | Turbidity (NTU) | TSS (mg/L) | Turbidity (NTU) | TSS (mg/L) | Turbidity (NTU) | TSS (mg/L) |
| May 25, 2022 | 1.1 | 1 | 1.7 | 1 | 2.1 | 1 |
| Jun 30, 2022 | 1.9 | 2 | 7.8 | 4.5 | 1.3 | ND |
| Jul 20, 2022 | 0.3 | ND | 1.4 | 1 | 0.72 | ND |
| Aug 17, 2022 | 0.28 | 1 | 0.4 | 1 | 0.57 | ND |
| Sep 27, 2022 | ND | 1 | 0.25 | ND | 0.18 | ND |

Notes: Samples measured below the PQL are reported as ND. PQL is 2 mg/L through May 2022, and 1 mg/L thereafter for TSS, and 0.1 NTU for turbidity.

### Drawdown Turbidity and Total Suspended Solids

As described in Section 4.1.1, turbidity and TSS samples are collected under drawdown conditions at three transect locations (ROSS4 through 6; see Attachment A, pp. 2, 3, and 5). Samples were collected three times between fall and spring 2021-2022 and are being collected three times between fall and spring 2022-2023, for a total of six transect sampling events. Sampling at the mouths of 11 tributaries into Ross Lake has been and is being conducted twice between fall and spring (2021-2022 and 2022-2023) for a total of four events. A third tributary sampling event was conducted in May 2022 to provide additional TSS and turbidity data during spring conditions. 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. These stations are described in Table 4.1-1 and can be viewed on the maps in Attachment A.

Results from the first three events conducted on December 1, 2021, March 17, 2022, and May 11, 2022, are shown in Table 5.1-3. Transect results were largely consistent within each transect in December (Table 5.1-3), and turbidity and TSS remained relatively low at all three transects. Significantly higher turbidity and TSS levels were observed during the March transect survey at all three transects coincident with windy and wet conditions in the field at the time of the survey. The May transect survey showed lower turbidity and TSS levels relative to the March survey, but higher levels overall relative to the December survey. A second round of transect surveys will be conducted over December 2022 – May 2023.

**Table 5.1-3. Results from turbidity and TSS transects at the Ross Lake erosional areas (winter 2021–spring 2022).**

| Date / Reservoir Elevation (ft) (NAVD 88 and CoSD) | Distance along Transect (m) | ROSS4 | | ROSS5 | | ROSS6 | |
|---|---|---|---|---|---|---|---|
| | | Turbidity (NTU) | TSS (mg/L) | Turbidity (NTU) | TSS (mg/L) | Turbidity (NTU) | TSS (mg/L) |
| Dec 1, 2021 1,591 (1,585) | 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 |
| March 17, 2022 1,538 (1,532) | 0 | 9.2 | 8 | 19 | 18 | 9.6 | 13 |
| | 100 | 65 | 151 | 130 | 89 | 16 | 24 |
| | 200 | 70 | 70 | 21 | 23 | 70 | 98 |
| | 300 | 22 | 26 | 2.3 | 2 | 3.2 | 2 |
| | 400 | 23 | 24 | 3.2 | 2 | 2.6 | ND |
| May 11, 2022 1,534 (1,527) | 0 | 5.1 | 3 | 16 | 22 | 6.1 | 22 |
| | 100 | 3 | 2.5 | 4.5 | 6 | 5.5 | 12 |
| | 200 | 4.5 | 3.5 | 6.8 | 7 | 18 | 39 |
| | 300 | 14 | 18 | 2 | ND | 18 | 41 |
| | 400 | 3.1 | 3 | 2.4 | 2 | 10 | 19 |

Notes: All elevations in the table are North American Vertical Datum 1988 (NAVD 88) with City of Seattle Datum (CoSD) value in parentheses.[8]

ROSS4 = Ross Lake erosional area north; ROSS5 = Ross Lake erosional area central; ROSS6 = Ross Lake erosional area south.

Samples measured below the PQL are reported as ND. PQL is 2 mg/L for TSS and 0.1 NTU for turbidity.

### Tributary Turbidity and Total Suspended Solids

Results from tributary turbidity and TSS sampling from December 2021, March 2022, and May 2022 are shown in Table 5.1-4 and 5.1-5 respectively. Samples were collected at the tributary mouths and within Ross Lake just downstream of the tributary mouths. Turbidity and TSS sample results from Ross Lake tributaries (shown with “A” in the tributary Site ID or as ≤ 1 in the case of Ruby Creek [TRIB11]) exhibit a broader range of values than samples collected in Ross Lake (shown with “B” in the tributary Site ID or as ≤ 5 in the case of Ruby Creek [TRIB11]). The highest values were measured in the Skagit River at the international boundary (TRIB1) in December 2021 and Ruby Arm (TRIB11) in March 2022. The mouth of Little Beaver Creek (TRIB3B) showed high TSS and turbidity levels in March but was otherwise comparable to other sites in December and May. Turbidity at the mouth of Dry Creek (TRIB5B) was similarly high in May 2022 (38 NTUs). The reservoir elevation at the time of sampling (1,591-1,592 ft NAVD 88; 1,585-1,586 ft CoSD) did not expose any appreciable varial zone or erosive substrates at TRIB6A

8 As described in Section 2.3 of the RSP, the CoSD requires a conversion to NAVD 88 in order to be comparable with elevations measured and presented elsewhere in analyses and discussions surrounding Project relicensing. To convert to NAVD 88, 6.26 feet must be added to Ross Lake WSE in CoSD, 6.36 feet added to Diablo Lake WSE, and 6.51 feet added to WSE for Gorge Lake.

(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. Field safety conditions precluded collection of samples at Silver Creek (TRIB2A and TRIB2B) in 2022, upstream location of Devil's Creek (TRIB6A) in 2021, Big Beaver Creek (TRIB8A), Pierce Creek (TRIB9A), and Ruby Creek (TRIB11 at ≤1-m) during some of the events

In addition to the turbidity and TSS sampling conducted as part of the RSP, sampling at the Skagit River at International Border (TRIB1), Little Beaver Creek mouth (TRIB3A), Lightning Creek mouth (TRIB4A), Big Beaver Creek mouth (TRIB5A) and Ruby Creek mouth (TRIB11) continued through the summer months to support CE-QUAL-W2 model development. These results are included in Tables 5.1-4 and 5.1-5 for turbidity and TSS, respectively. TSS was generally low (not detectable) in the summer in these tributaries, as were the corresponding turbidity levels, with the exception of Little Beaver and Dry Creek, which exhibited high TSS in March and May, respectively (Table 5.1-5). These results are consistent with the low turbidity and TSS levels observed over the summer months at the three monthly sampling locations in Ross Lake (see Table 5.1-1).

**Table 5.1-4. Results of turbidity sampling in Ross Lake tributaries (fall 2021–summer 2022).**

| Site ID | Site Name | Depth (m) | Turbidity (NTU) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Nov 30-Dec 1, 2021 | Mar 16-17, 2022 | May 11, 2022 | May 24, 2022[1] | Jun 22, 2022[1] | Jul 20, 2022[1] | Aug 17, 2022[1] | Sep 27, 2022[1] |
| TRIB1 | Skagit River at International Boundary | <1 | 100 (100) | 3.5 | 5.7 | 5.7 (5.9) | 5.6 | 0.34 | 0.29 (0.29) | 0.5 |
| TRIB2A | Silver Creek – Mouth[2] | <1 | 1.1 | - | - | - | - | - | - | - |
| TRIB2B | Silver Creek – Lake[2] | <1 | 17 | - | - | - | - | - | - | - |
| TRIB3A | Little Beaver Creek – Inlet | <1 | 17 | 0.43 | 1.1 | 1.3 | 1.4 (1.5) | 0.33 | 0.21 | 0.3 |
| TRIB3B | Little Beaver Creek – Lake | <1 | 17 | 38 | 1.2 | - | - | - | - | - |
| TRIB4A | Lighting Creek – Inlet | <1 | 15 | 0.51 | 0.76 | 1.6 | 7.6 | 0.37 | 0.19 | 0.17 (0.14) |
| TRIB4B | Lightning Creek – Lake | <1 | 12 | 9.5 | 1.2 | - | - | - | - | - |
| TRIB5A | Dry Creek – Upstream | <1 | 4.1 | 0.42 | 0.83 | - | - | - | - | - |
| TRIB5B | Dry Creek – Mouth | <1 | <1 | 5.6 | 36 | - | - | - | - | - |
| TRIB6 | Devil's Creek[3] | <1 | - | 0.51 | 0.98 | - | - | - | - | - |
| TRIB7A | May Creek – Inlet[4] | <1 | - | 0.22 | 0.34 | - | - | - | - | - |
| TRIB7B | May Creek – Mouth[4] | <1 | - | 1.1 | 2 | - | - | - | - | - |
| TRIB8A | Big Beaver Creek – Upstream[5] | <1 | 7 | 0.56 | - | 1.1 | 5.2 | 2 | 1.9 | 0.54 |
| TRIB8B | Big Beaver Creek – Mouth | <1 | 8 | 0.41 | 0.86 | - | - | - | - | - |
| TRIB9A | Pierce Creek – Upstream[5] | <1 | 1.2 | 0.21 | - | - | - | - | - | - |
| TRIB9B | Pierce Creek – Mouth | <1 | 1.2 | 0.15 | 0.87 | - | - | - | - | - |
| TRIB10A | Roland Creek – Upstream | <1 | 1.4 | 0.29 | 0.21 | - | - | - | - | - |
| TRIB10B | Roland Creek – Mouth | <1 | 1.4 | 0.47 | 1.1 | - | - | - | - | - |
| TRIB11 | Ruby Arm[6] | <1 | 18 | 60 | 1.1 | 1.5 | 13 | 0.32 (0.26) | 0.27 | 0.32 |
| | | 5 | 40 | - | - | - | - | - | - | - |

Notes: Samples measured below the PQL (Turbidity = 0.1 NTU) are reported as ND.
Field duplicate results shown in parenthesis.

1 Tributary sampling events from May 24, 2022 through Sep 27, 2022 were done at a limited set of tributaries to provide inputs for the model development, separate from the fall-spring tributary sampling that was completed under the RSP, as amended by FERC. Tributary mouth sampling was not required under the RSP for these dates at TRIB2A/B, TRIB3B, TRIB4B, TRIB7A/B, TRIB8B, TRIB9A/B, TRIB10A/B, and TRIB11 at 5 ft depth.

2 Silver Creek – Mouth (TRIB2A) and Silver Creek – Lake (TRIB2-B) were not sampled in March 16-17, 2022, and May 11, 2022 because the stream's flow was subterranean during these events.

3 Devil's Creek (TRIB6) – Sampling occurred only at the mouth because the upstream location is inaccessible by boat or by foot. During the November 30 – December 1, 2021 event a sample could not be collected even at the mouth because the tributary was inaccessible by boat due to a log jam.

4 May Creek – Inlet/Mouth (TRIB7A/B) were not sampled during the November 30 – December 1, 2021 event because TSS/turbidity was collected in the vicinity (ROSS6) as part of Ross Transect survey.

5 Big Beaver Creek – Upstream (TRIB8A) and Pierce Creek – Upstream (TRIB9A) were not sampled during the May 11, 2022 event because of site safety conditions (bear activity in the vicinity).

6 Ruby Arm (TRIB11) – The upstream sample ("trib") required under the RSP could not be collected during the November 30 – December 1, 2021 and March 16-17, 2022 sampling events because the upstream location was inaccessible due to high flows and unsafe site conditions. An additional sample was collected from within Ruby Arm at 5 ft depth during the November 30 – December 1, 2021 event as a substitute for the upstream sample.

**Table 5.1-5. Results of TSS sampling in Ross Lake tributaries (fall 2021– summer 2022).**

| Site ID | Site Name | Depth (m) | TSS (mg/L) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Nov 30-Dec 1, 2021 | Mar 16-17, 2022 | May 11, 2022 | May 24, 2022[1] | Jun 22, 2022[1] | Jul 20, 2022[1] | Aug 17, 2022[1] | Sep 27, 2022[1] |
| TRIB1 | Skagit River at International Boundary | <1 | 88 (86) | 3 | 7 | 5 (7) | 3.5 | ND | ND (1) | 1 |
| TRIB2A | Silver Creek – Mouth[2] | <1 | ND | - | - | - | - | - | - | - |
| TRIB2B | Silver Creek – Lake[2] | <1 | 24 | - | - | - | - | - | - | - |
| TRIB3A | Little Beaver Creek – Inlet | <1 | 31 | ND | ND | 2 | ND (2) | 1.3 | ND | ND |
| TRIB3B | Little Beaver Creek – Lake | <1 | 27 | 93 | ND | - | - | - | - | - |
| TRIB4A | Lighting Creek – Inlet | <1 | 12 | 3 | ND | 2 | 10.5 | ND | ND | ND |
| TRIB4B | Lightning Creek – Lake | <1 | 8 | 14 | 3 | - | - | - | - | - |
| TRIB5A | Dry Creek – Upstream | <1 | 3 | ND | ND | - | - | - | - | - |
| TRIB5B | Dry Creek – Mouth | <1 | 8 | 17 | 84 | - | - | - | - | - |
| TRIB6 | Devil's Creek[3] | <1 | - | 2 | ND | - | - | - | - | - |
| TRIB7A | May Creek – Inlet[4] | <1 | - | ND | ND | - | - | - | - | - |
| TRIB7B | May Creek – Mouth[4] | <1 | - | ND | 2 | - | - | - | - | - |
| TRIB8A | Big Beaver Creek – Upstream[5] | <1 | 18 | ND | - | ND | 9.5 | 1.7 | 2 | ND |
| TRIB8B | Big Beaver Creek – Mouth | <1 | 19 | ND | 2 | - | - | - | - | - |
| TRIB9A | Pierce Creek – Upstream[5] | <1 | ND | ND | - | - | - | - | - | - |
| TRIB9B | Pierce Creek – Mouth | <1 | ND | ND | ND | - | - | - | - | - |
| TRIB10A | Roland Creek – Upstream | <1 | ND | ND | ND | - | - | - | - | - |
| TRIB10B | Roland Creek – Mouth | <1 | ND | ND | 2 | - | - | - | - | - |
| TRIB11 | Ruby Arm[6] | <1 | 8 | 145 | ND | ND | 12.5 | ND (ND) | ND | ND |
| | | 5 | 39 | - | - | - | - | - | - | - |

Notes: Samples measured below the PQL for TSS (2 mg/L through June 2022, and 1 mg/L thereafter) are reported as ND.
Field duplicate results shown in parenthesis.

1 Tributary sampling events from May 24, 2022 through Sep 27, 2022 were done at a limited set of tributaries to provide inputs for the model development, separate from the fall-spring tributary sampling that was completed under the RSP, as amended by FERC. Tributary mouth sampling was not required under the RSP for these dates at TRIB2A/B, TRIB3B, TRIB4B, TRIB7A/B, TRIB8B, TRIB9A/B, TRIB10A/B, and TRIB11 at 5 ft depth.

2 Silver Creek – Mouth (TRIB2-A) and Silver Creek – Lake (TRIB2-B) were not sampled in March 16-17, 2022, and May 11, 2022 because the stream's flow was subterranean during these events.

3 Devil's Creek (TRIB6) – Sampling occurred only at the mouth because the upstream location is inaccessible by boat or by foot. During the November 30-December 1, 2021 event a sample could not be collected even at the mouth because the tributary was inaccessible by boat due to a log jam.

4 May Creek – Inlet/Mouth (TRIB7A/B) were not sampled during the November 30 – December 1, 2021 event because TSS/turbidity was collected in the vicinity (ROSS6) as part of Ross Transect survey.

5 Big Beaver Creek – Upstream (TRIB8A) and Pierce Creek – Upstream (TRIB9A) were not sampled during the May 11, 2022 event because of site safety conditions (bear activity in the vicinity).

6 Ruby Arm (TRIB11) – The upstream sample ("trib") required under the RSP could not be collected during the November 30 – December 1, 2021 and March 16-17, 2022 sampling events because the upstream location was inaccessible due to debris. An additional sample was collected from within Ruby Arm at 5 ft depth during the November 30 – December 1, 2021 event as a substitute for the upstream sample.

#### 5.1.1.4 Fecal Coliform/*E. Coli*

FC concentrations in the reservoirs were largely below quantification limits during both years, although several samples did contain detectable colony-forming units (CFU) (Table 5.1-6). The highest FC concentrations were recorded in June 2021 (600 CFU/100 mL at ROSS8). Similarly, in 2022 the highest FC bacterial levels were observed in June, but all locations reported values of 5 CFU/100 mL or less.

*E. coli* concentrations closely mirrored the FC results (Table 5.1-6). August and September results were at or below the quantification limit. For primary contact recreation, WAC 173-201A-200(2)(b) requires *E. coli* levels to be 100 CFU /100 mL or less (as a geometric mean when more than 3 samples are available), with not more than 10 percent (or any single sample when less than 10 samples exist for a site) obtained within the averaging period exceeding 320 CFU/100 mL. Except for the June 2021 sample at ROSS8 (measured as FC), all other samples were below the primary contact recreation criteria. Considering that the highest FC or *E. coli* measurement in 2022 was less than 5 CFU/100 mL, the 2021 exceedance appears to be an isolated exceedance in the vicinity of Ross Lake Resort.

**Table 5.1-6. Monthly fecal coliform and *E. coli* sampling results (June-September 2021, June-September 2022).**

| Date | ROSS7 | | ROSS8 | | ROSS9 | | ROSS10 | | ROSS11 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | FC | *E. coli* | FC | *E. coli* | FC | *E. coli* | FC | *E. coli* | FC | *E. coli* |
| Jun 30, 2021 | 3 (5) | - | 600 | - | ND | - | 3 | - | 3 | - |
| Jul 26, 2021 | ND | - | ND (ND) | - | ND | - | ND | - | ND | - |
| Aug 17, 2021 | 2 | - | 2 | 2 | ND (ND) | - | ND | - | ND (ND) | - |
| Sep 14, 2021 | 2 | ND | 11 | 2 | ND | ND | ND (ND) | ND (ND) | ND | ND |
| Jun 21, 2022 | ND | ND | 5 | 4 | ND | ND | 5 | 5 | 1 (ND) | 1 (ND) |
| Jul 19, 2022 | 2 | 2 | ND | ND | ND | ND | ND (ND) | ND (ND) | 2 | ND |
| Aug 18, 2022 | 1 | 1 | 13 (12) | 11 (8) | 1 | 1 | ND | ND | ND | ND |
| Sep 28, 2022 | ND (ND) | ND (ND) | 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 are reported as ND (2 CFU/100 mL for samples in 2021 and most samples in 2022; some 2022 bacterial samples were reported with a lower quantitation limit of 1 CFU/100 mL in 2022).
Field duplicate results are shown in parenthesis.
*E. coli* was measured at ROSS8 in August 2021 and at all sites from September 2021 onward.

### 5.1.1.5 Nutrients and Productivity

**Nutrients and Chlorophyll *a***

Nutrients and chlorophyll *a* concentrations measured at Ross Lake tributary mouths are shown in Figures 5.1-11a and 5.1-11b. Inorganic nitrogen entered predominantly in the form of nitrate, with Big Beaver Creek (TRIB8) showing the highest dissolved inorganic nitrogen (DIN) concentrations. Total Kjeldahl nitrogen (TKN), which provides an indication of the organic nitrogen, was undetectable at all tributary mouth locations sampled; however, the TKN quantitation limit was relatively high at 0.2 mg/L, thus tributaries could have contributed lower levels of organic nitrogen, considering that ammonium ($NH_4$) was also largely below the quantitation limit. Inorganic nitrogen inputs, in the form of nitrate, were highest in spring but remained detectable throughout the summer months, but at lower concentrations.

The PQL for total phosphorus (TP) and orthophosphate were both 10 µg/L (shown by the horizontal dashed line in Figure 5.1-11b), but the method detection limit (MDL) for both was 3 µg/L. So, even though the samples are plotted as non-detect based on the PQL (because this is the level at which the laboratory is accredited by Ecology to report the results), some of the phosphorus concentrations were observed to be above the MDL. Nonetheless, these are still very low levels of phosphorus. The highest TP concentrations were observed at Ruby Creek (TRIB11). The majority of the phosphorus inputs occurred in May and June. Chlorophyll *a* levels were low but observed to be above detection limits at several tributary inflows in spring and again later in summer and early fall. Considering that nitrogen levels in the tributaries remained well above nutrient limiting levels for phytoplankton (typically about 25 µg/L), and phosphorus was largely low or non-detect, it appears that conditions in the tributaries are most likely phosphorus limiting for primary production. These low levels of nutrients and chlorophyll *a* concentrations at the tributary mouths indicate oligotrophic conditions in the watershed (based on the average concentrations of 8 µg/L, 660 µg/L, 1.7 µg/L for phosphorus, nitrogen and chlorophyll *a*, respectively, for oligotrophic systems in Wetzel [2001]).

Nutrient and chlorophyll *a* levels at the Ross Lake forebay location (ROSS12) are shown in Figures 5.1-12a and 5.1-12b. The patterns largely follow the tributary inputs, with most of the DIN in the reservoir that is above the PQL in the form of nitrate. Phosphorus samples above the PQL were reported primarily for June and July following snowmelt inputs. Chlorophyll *a* levels were low throughout the summer, with the highest value of 1.2 µg/L observed in August in the metalimnion sample. Epilimnetic values from June through August were less than 0.94 µg/L, indicative of oligotrophic conditions (Carlson 1977). Even though more light is available in the epilimnion, higher chlorophyll *a* levels were observed in the metalimnion, suggesting that nutrients available for primary production in the forebay originate from cooler tributary inflows, or from nutrients diffusing upward in the water column. However, the very low chlorophyll *a* levels in the water column and high DO at depth indicate only a limited amount of organic matter loading to, and nutrient cycling from, the sediments. This is evident in the low TP levels in the hypolimnion samples from near the sediment-water interface, which are not appreciably different from the epilimnion and metalimnion. Similar to the tributaries, the low levels of nutrients and chlorophyll *a* in the Ross Lake forebay indicate that Ross Lake is oligotrophic.

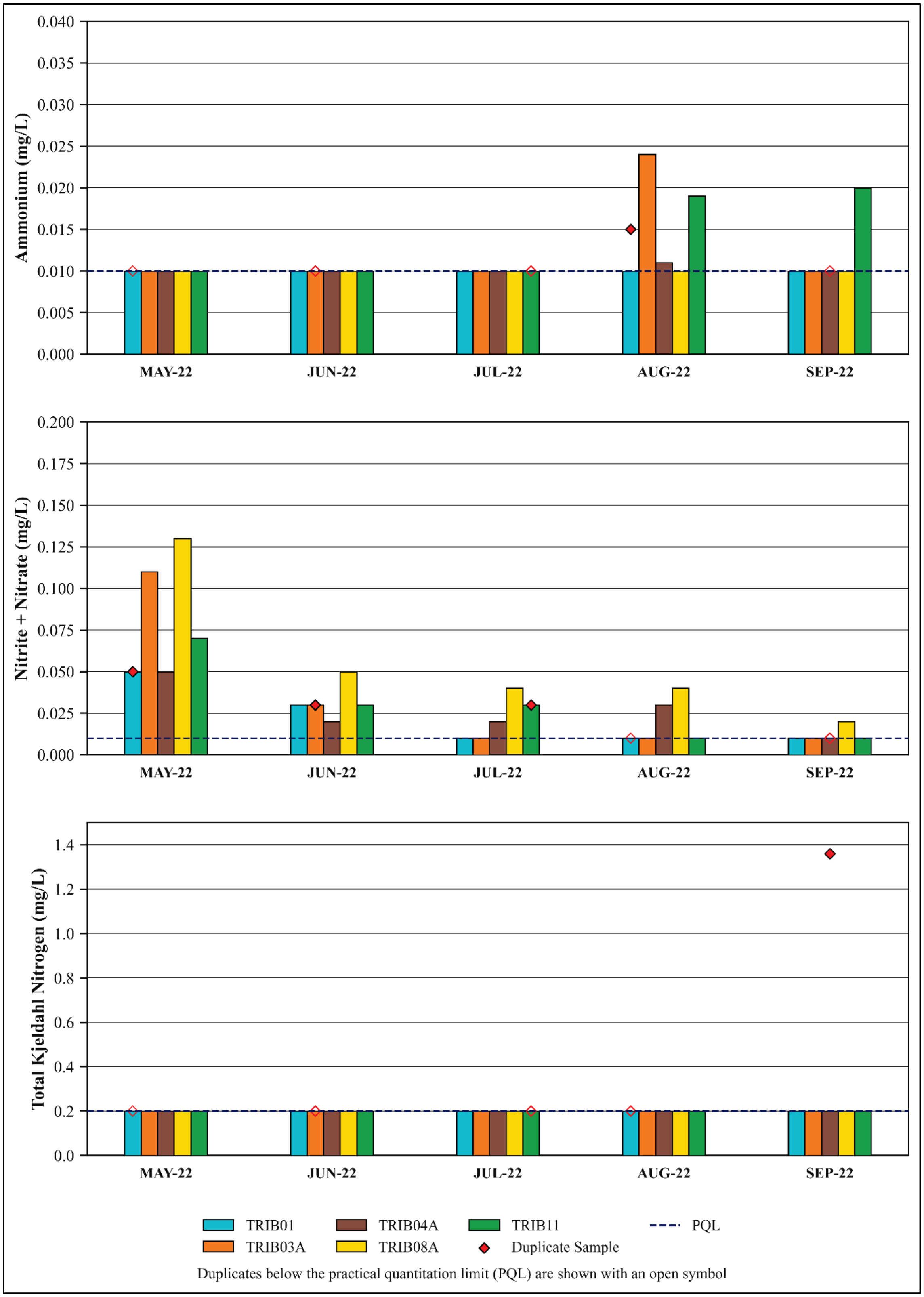



**Figure 5.1-11a. Nutrients concentrations at Ross Lake tributaries: International Border (TRIB01), Little Beaver Creek (TRIB03), Lightning Creek (TRIB04), Big Beaver Creek (TRIB08) and Ruby Creek (TRIB11) (2022).**

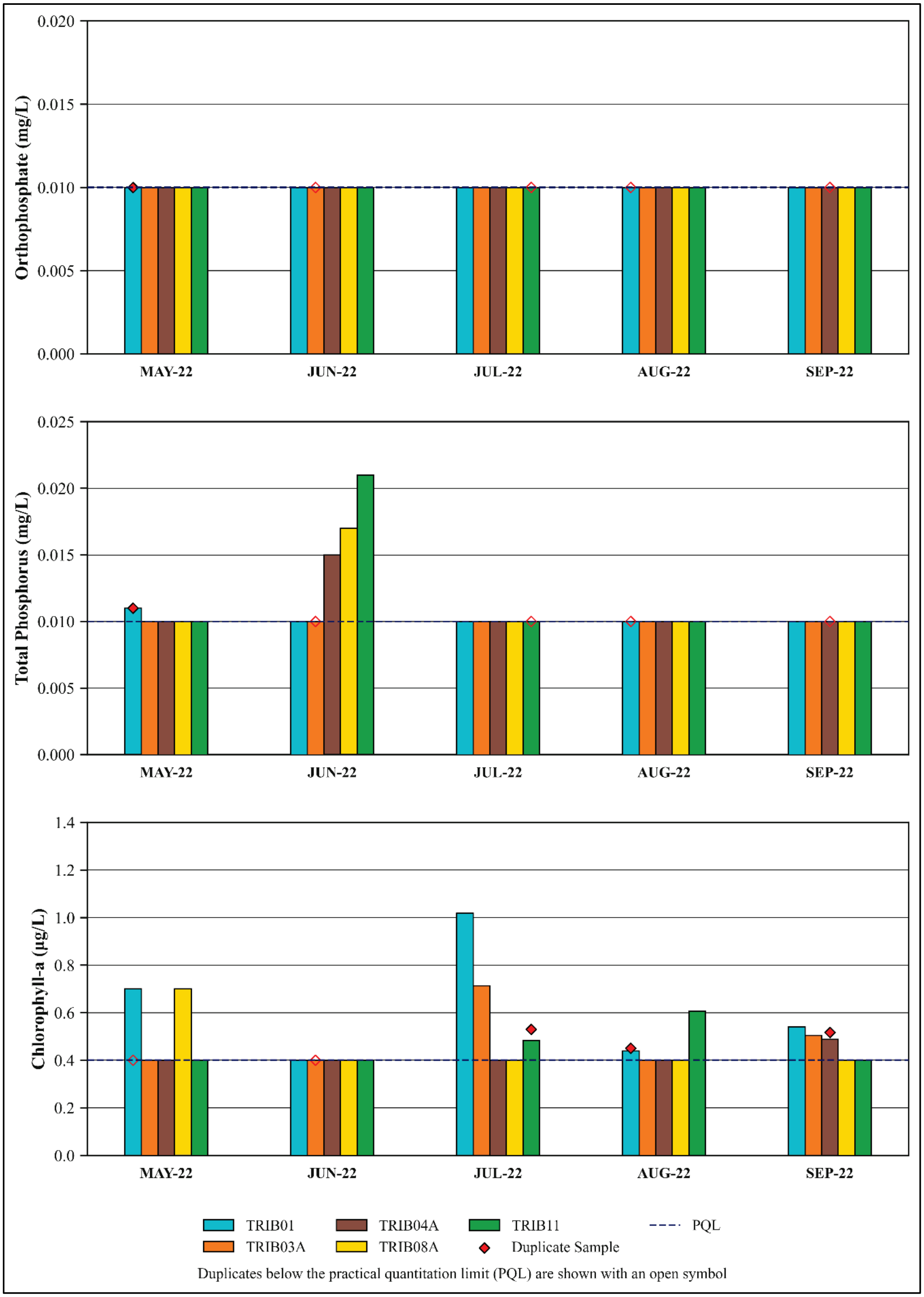



**Figure 5.1-11b. Nutrients and chlorophyll *a* concentrations at Ross Lake tributaries: International Border (TRIB01), Little Beaver Creek (TRIB03), Lightning Creek (TRIB04), Big Beaver Creek (TRIB08) and Ruby Creek (TRIB11) (2022).**

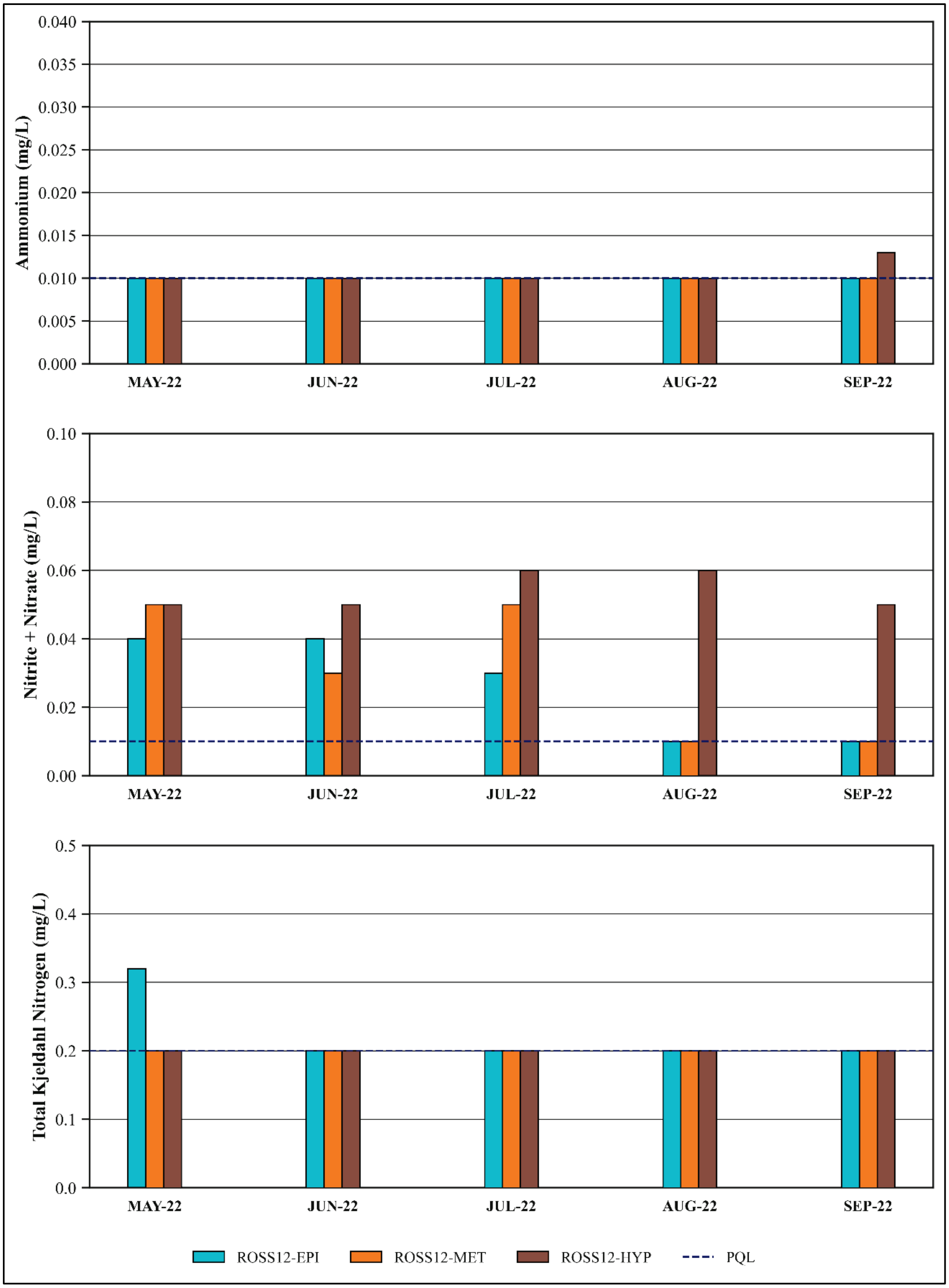



**Figure 5.1-12a. Nutrients concentrations at Ross Lake log boom, epilimnion, metalimnion, and hypolimnion (ROSS12) (2022); PQL = practical quantitation limit.**

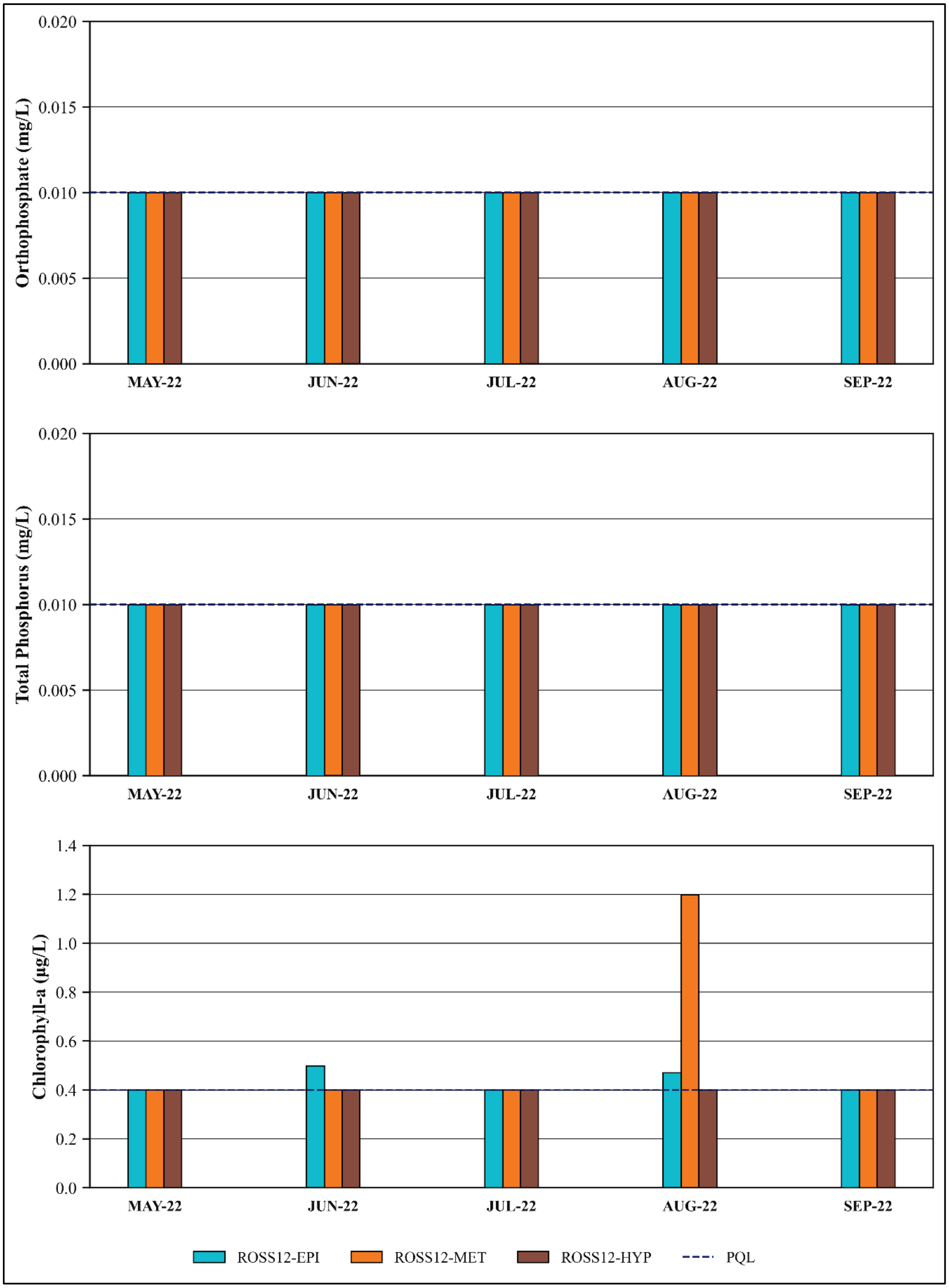



**Figure 5.1-12b.** **Nutrients and chlorophyll *a* concentrations at Ross Lake log boom, epilimnion, metalimnion, and hypolimnion (ROSS12) (2022); PQL = practical quantitation limit.**

### Organic Carbon and CBOD

Tributary organic carbon and CBOD concentrations are shown in Figure 5.1-13. Total organic carbon (TOC) ranged from 0.3 to 1.4 mg/L, with the highest TOC levels observed at the international border (TRIB1). The majority of the organic carbon was dissolved organic carbon (DOC). Particulate organic carbon (POC) concentrations were estimated as the difference between TOC and DOC and were generally low. The CBOD levels were largely below the PQL throughout the year, except during the snowmelt period when a CBOD of 10 mg/L was observed at Big Beaver Creek mouth (TRIB8A). The overall low levels of particulate organic matter and CBOD are consistent with an oligotrophic condition indicated by the nutrients and chlorophyll *a* data.

The patterns of relatively low levels of organic carbon, largely in dissolved form, were also evident at the Ross Lake forebay location (Figure 5.1-14). CBOD was largely non-detectable. There were no notable differences in the concentrations between the different limnetic zones, which is consistent with the overall low levels of phytoplankton in the water column and low organic matter loading from the tributary inflows.

### Total Inorganic Carbon and Alkalinity

Incoming alkalinity and total inorganic carbon (TIC) from tributary inflows are shown in Figure 5.1-15. Although TIC and alkalinity differed among the tributaries, both remained relatively consistent over time at each tributary mouth, indicating low levels of photosynthetic activity within the tributaries. Tributary pH levels also remained relatively constant, around 7-8, another indicator that photosynthetic activity is low (pH is discussed below).

Ross Lake forebay alkalinity and TIC are shown in (Figure 5.1-16). TIC remained within a relatively narrow range of 5-9 mg/L, with the lowest TIC measured in the June metalimnion sample, which coincided with the lowest alkalinity of 22.2 mg/L. These observations are consistent with the relatively low chlorophyll *a* levels discussed previously.

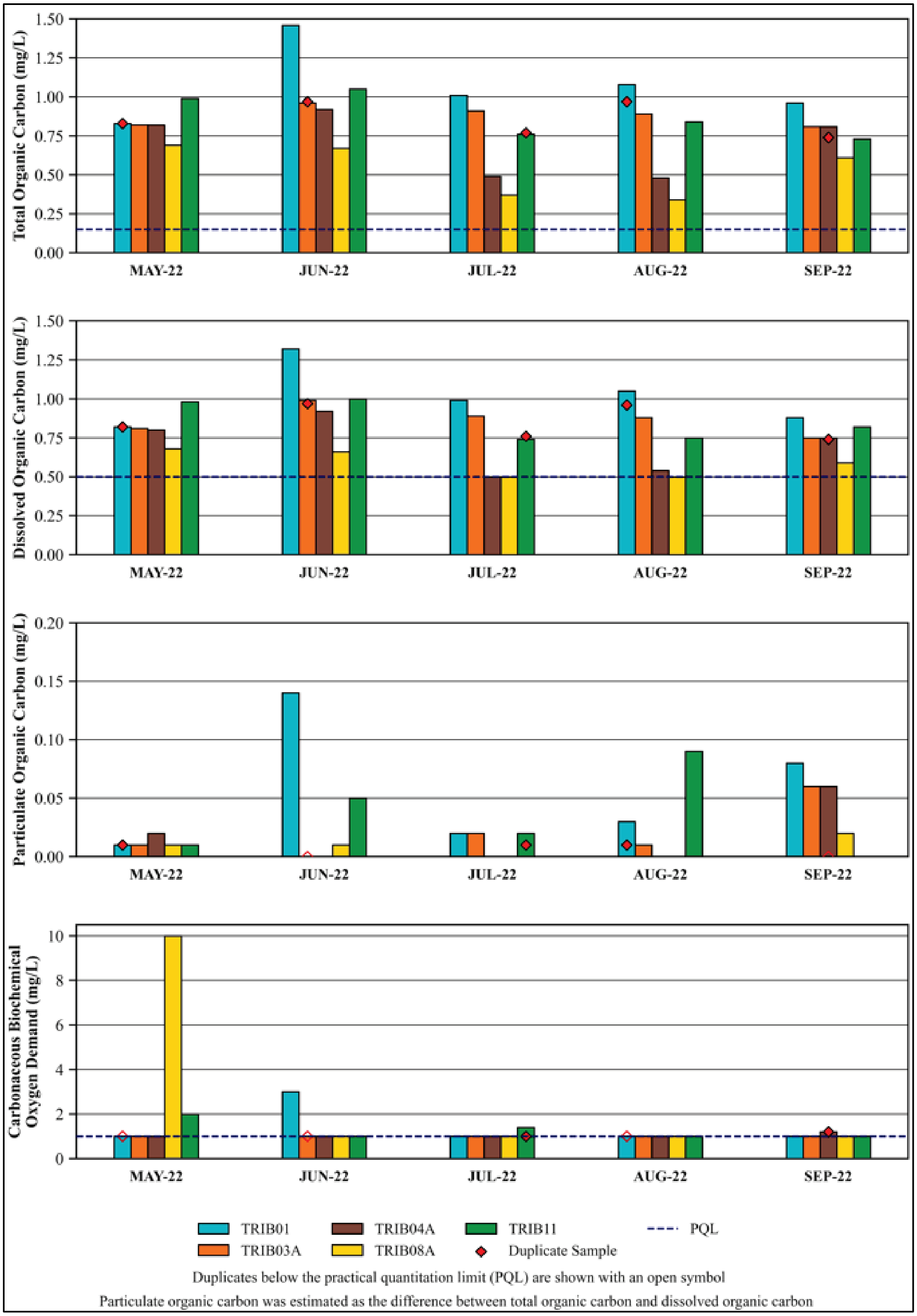



**Figure 5.1-13. Organic carbon and CBOD concentrations at Ross Lake tributaries: International Border (TRIB01), Little Beaver Creek (TRIB03), Lightning Creek (TRIB04), Big Beaver Creek (TRIB08) and Ruby Creek (TRIB11) (2022).**

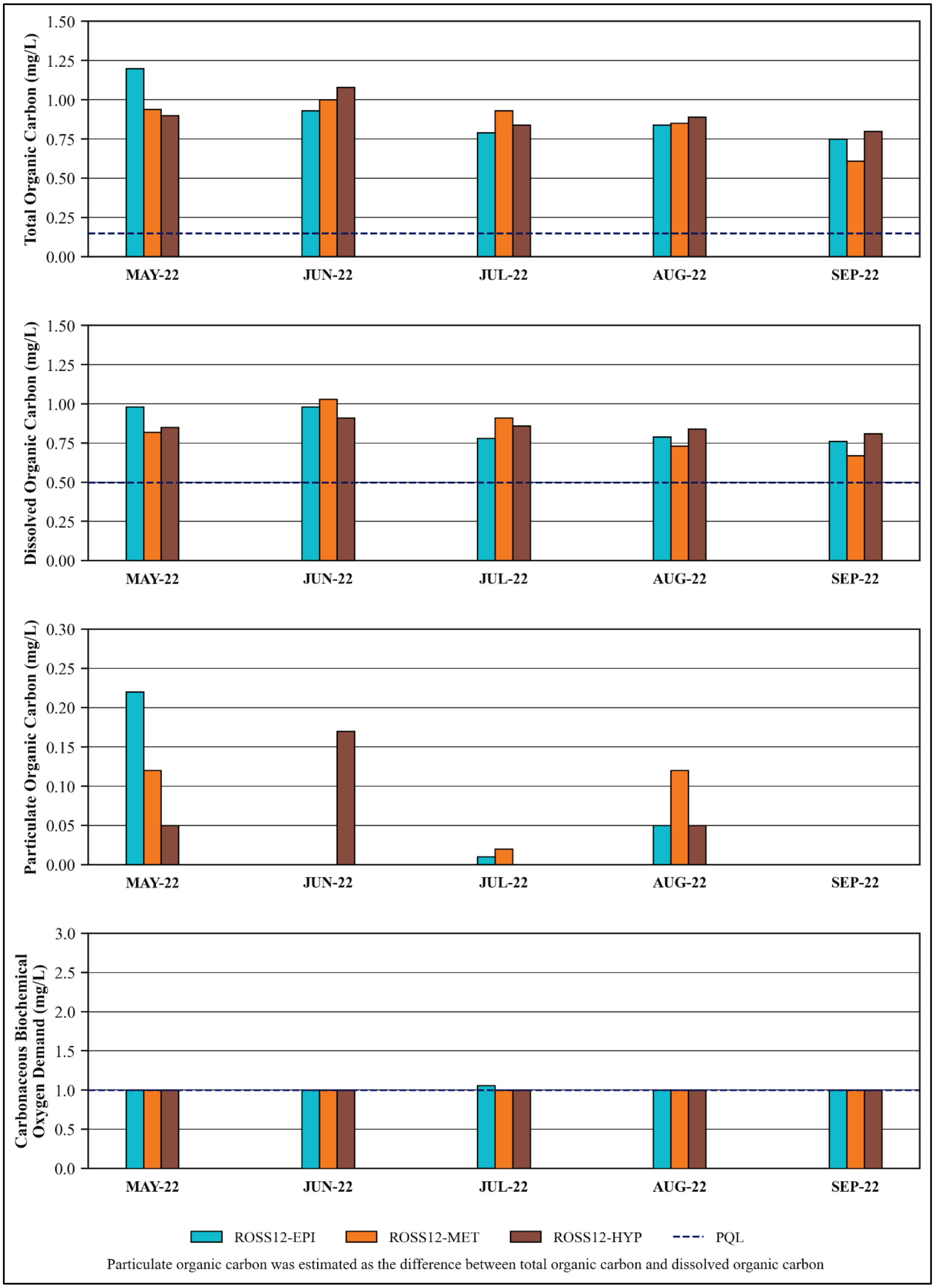



**Figure 5.1-14. Organic carbon and CBOD concentrations at Ross Lake log boom, epilimnion, metalimnion, and hypolimnion (ROSS12) (2022); PQL = practical quantitation limit.**

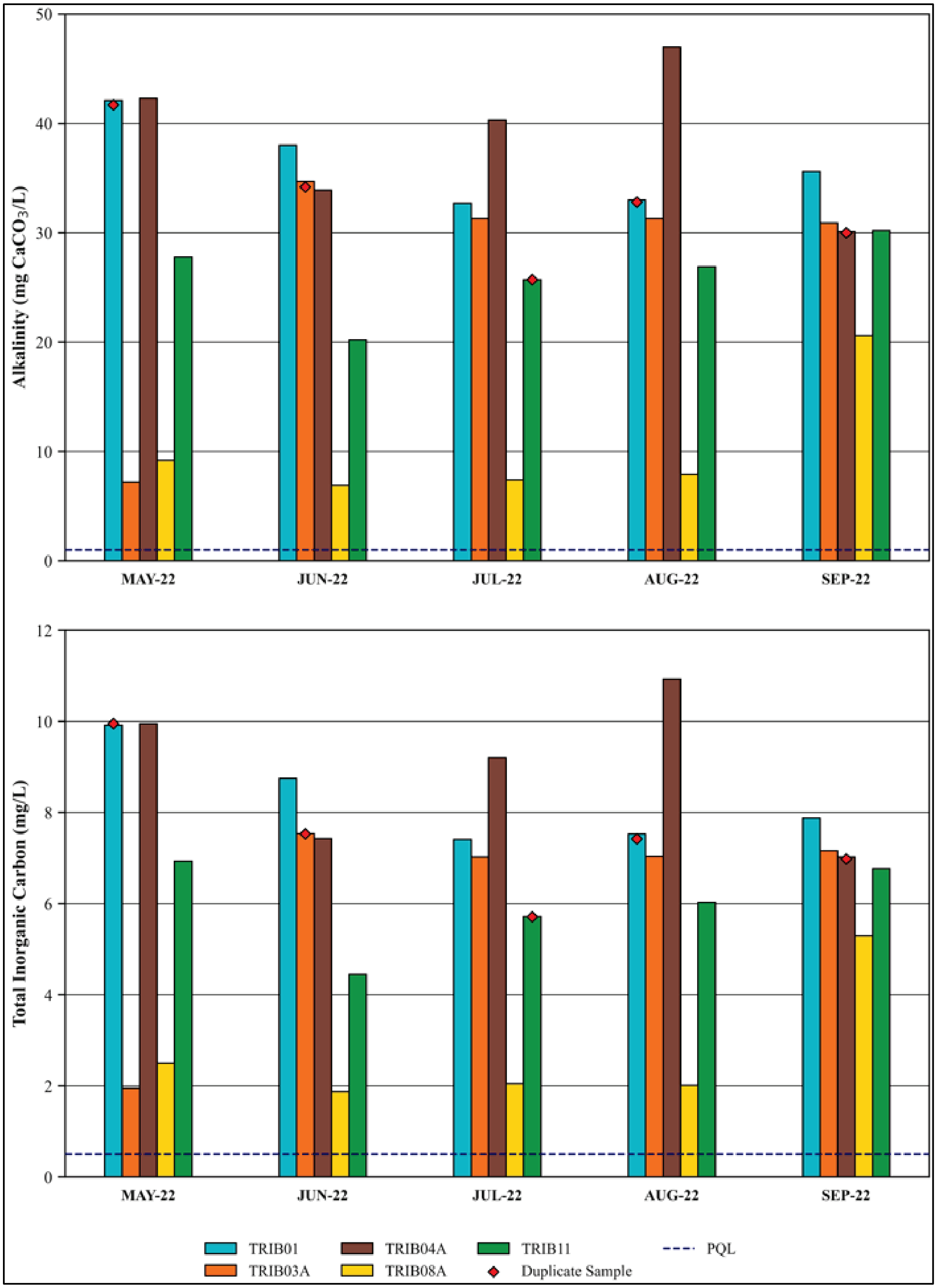



**Figure 5.1-15. Inorganic carbon and alkalinity in Ross Lake tributaries: International Border (TRIB01), Little Beaver Creek (TRIB03), Lightning Creek (TRIB04), Big Beaver Creek (TRIB08) and Ruby Creek (TRIB11) (2022); PQL = practical quantitation limit.**

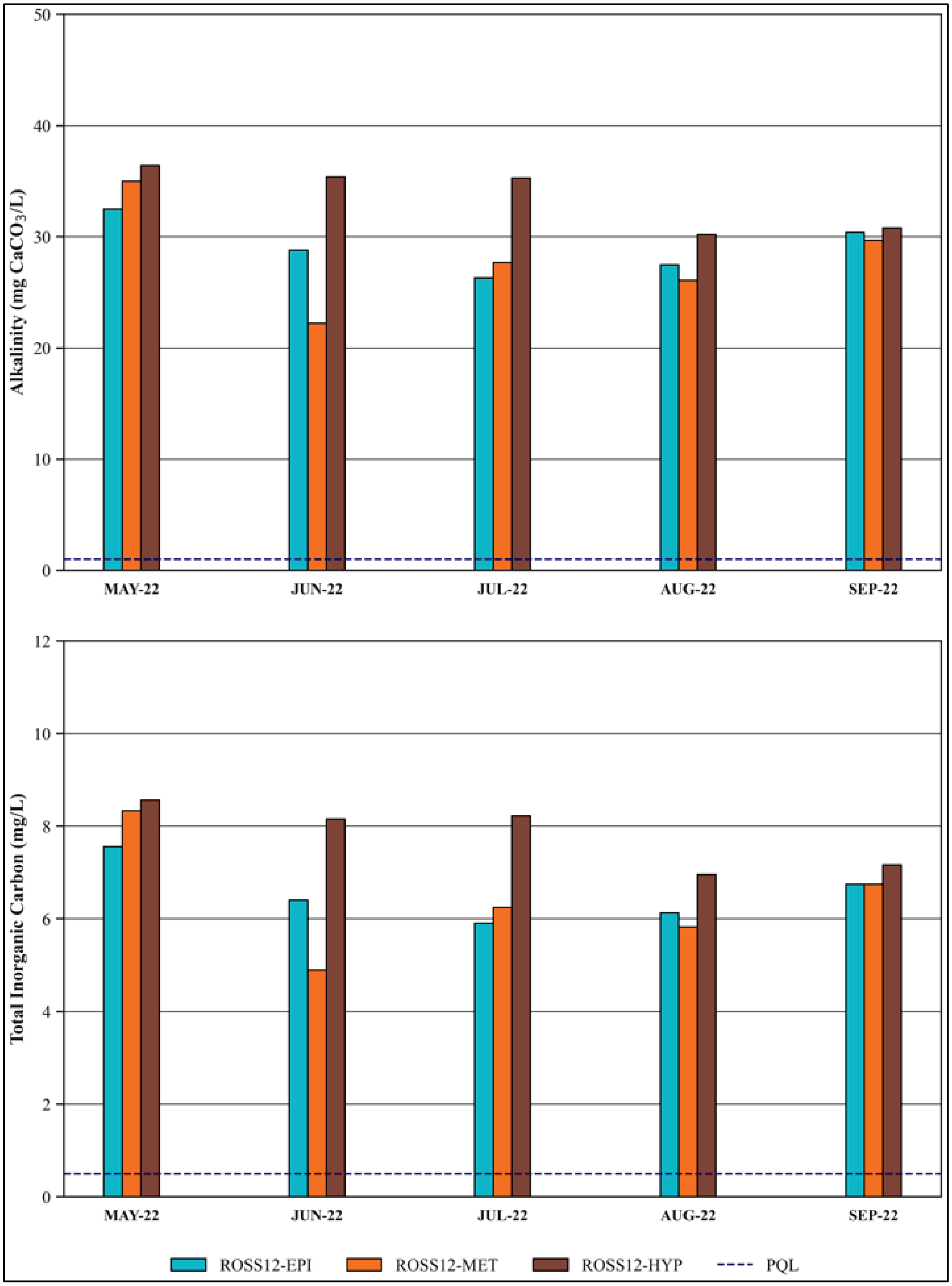



**Figure 5.1-16. Inorganic carbon and alkalinity at Ross Lake log boom, epilimnion, metalimnion, and hypolimnion (ROSS12) (2022); PQL = practical quantitation limit.**

#### 5.1.1.6 Phytoplankton Taxonomy

Laboratory results of basic taxonomic analysis for phytoplankton were available for May, July, and August 2022. Phytoplankton taxonomic analysis could not be performed for the June samples because the samples received by the laboratory froze during shipping, rendering them unviable for cell counts. The results for Ross Lake tributaries and the Ross Lake forebay are shown grouped by the top five major taxa in Tables 5.1-7 and 5.1-8, respectively. The objective of the high-level taxonomic analysis is to provide basic information on the dominant phytoplankton species entering from tributaries and those that successfully grow within Ross Lake. These results also show the succession of different phytoplankton groups over time as conditions change within the reservoir and in the tributaries.

**Table 5.1-7. Ross Lake tributary phytoplankton taxonomy (May-August 2022).**

| Date | Taxon Rank | International Border (TRIB01) | | Little Beaver Creek (TRIB03) | | Lightning Creek (TRIB04) | | Big Beaver Creek (TRIB08) | | Ruby Creek (TRIB11) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Taxon | Abundance (%) | Taxon | Abundance (%) | Taxon | Abundance (%) | Taxon | Abundance (%) | Taxon | Abundance (%) |
| May 24, 2022 | 1st | *Navicula* spp. (*Gomphonema* spp.) | 51.7 (29) | *Leptolyngbya* spp. | 68.9 | *Gomphonema* spp. | 27.6 | *Fragilaria* spp. | 18.6 | *Achnanthidium* spp. Kützing | 22.5 |
| | 2nd | *Gomphonema* spp. (*Nitzschia* spp.) | 11 (17.3) | *Fragilaria* spp. | 7.7 | *Diatoma* spp. | 21 | *Achnanthidium* spp. Kützing | 18.3 | *Homoeothrix* spp. | 21.2 |
| | 3rd | *Synedra* spp. (*Diatoma* spp.) | 8.3 (16.6) | *Gomphonema* spp. | 5.6 | *Fragilaria* spp. | 12.3 | *Navicula* spp. | 11 | *Gomphonema* spp. | 16.7 |
| | 4th | *Diatoma* spp. (*Fragilaria* spp.) | 6.6 (13.6) | *Achnanthidium* spp. Kützing | 3.8 | *Hannaea arcus* (Ehrenberg) Patrick | 9.6 | *Eunotia* spp. | 10.3 | *Fragilaria* sp. | 11.1 |
| | 5th | *Amphora* spp. (*Navicula* spp.) | 5.6 (8) | *Diatoma* spp. | 2.5 | *Nitzschia* spp. | 8.3 | *Gomphonema* spp. | 8.3 | *Diatoma* spp. | 9.0 |
| Jul 21, 2022 | 1st | *Dinobryon* spp. | 94.4 | *Dinobryon* spp. | 63.5 | *Achnanthidium* spp. Kützing | 32.6 | *Planktolyngbya* spp. | 31.9 | *Dinobryon* spp. (*Dinobryon* spp.) | 54.4 (67.0) |
| | 2nd | *Asterionella formosa* Hassall | 3.2 | *Chrysococcus* sp. | 26.5 | *Gomphonema* spp. | 28.5 | *Achnanthidium* spp. Kützing | 16.0 | *Cryptomonas* spp. (*Cryptomonas* spp.) | 23.3 (15.1) |
| | 3rd | *Cryptomonas* spp. | 0.88 | *Cryptomonas* spp. | 5.2 | *Planktolyngbya* spp. | 15 | *Hannaea arcus* (Ehrenberg) Patrick | 11.8 | Unknown Chrysophyte spp. (including little round cysts) (*Asterionella formosa* Hassall) | 7.5 (14.3) |
| | 4th | *Fragilaria* spp. | 0.29 | *Asterionella formosa* Hassall | 3.9 | *Hannaea arcus* (Ehrenberg) Patrick | 9.3 | Unknown Chrysophyte sp. | 10.4 | *Asterionella formosa* Hassall (*Mallomonas* spp.) | 6.2 (0.8) |
| | 5th | *Ceratium hirundinella* (Möller) Dujardin | 0.29 | *Peridinium* spp. | 0.57 | Unknown Chrysophyte (cyst) sp. | 4.6 | *Ochromonas* spp. | 7.6 | *Ochromonas* spp. (*Fragilaria* spp.) | 1.6 (0.8) |
| Aug 17, 2022 | 1st | *Cyclotella* spp. (*Dinobryon* spp.) | 31.7 (48.4) | *Aphanocapsa* spp. | 53.7 | *Aphanocapsa* spp. | 57.9 | *Achnanthidium* spp. Kützing | 36.2 | *Dinobryon* spp. | 58.7 |
| | 2nd | *Dinobryon* spp. (*Cyclotella* spp.) | 26.8 (24.2) | *Dinobryon* spp. | 19.2 | *Achnanthidium* spp. Kützing | 14.9 | *Hannaea arcus* (Ehrenberg) Patrick | 23.5 | *Cyclotella* spp. | 18.2 |
| | 3rd | *Sphaerocystis* sp. (Unknown Chrysophyte sp.) | 15.5 (7.7) | *Cyclotella* spp. | 13.2 | *Dinobryon* spp. | 7 | *Gomphonema* spp. | 14.0 | *Aphanothece* spp. Nägeli | 14.2 |
| | 4th | *Cryptomonas* spp. (*Cryptomonas* spp.) | 12.2 (6.3) | *Chrysococcus* sp. | 5.2 | *Cyclotella* spp. | 7 | *Synedra* spp. | 9.4 | *Botryococcus braunii* Kützing | 5.7 |
| | 5th | Unknown Chrysophyte sp. (*Asterionella formosa* Hassall) | 6.1 (4.6) | Unknown Chrysophyte sp. | 4.4 | *Gomphonema* spp. | 4.1 | *Navicula* spp. | 5.5 | *Cryptomonas* spp. | 1.4 |

Notes: Values shown in parentheses are for duplicate samples.
Abundance is reported as a percentage, i.e., the total number of cells of a given taxon / the total cell count for all taxa combined.
Only the five most abundant taxa are shown for each sampling date.

**Table 5.1-8. Ross Lake Forebay (ROSS12) phytoplankton taxonomy (May–August 2022).**

| Date | Taxon Rank | Epilimnion | | Metalimnion | | Hypolimnion | |
|---|---|---|---|---|---|---|---|
| | | Taxon | Abundance (%) | Taxon | Abundance (%) | Taxon | Abundance (%) |
| May 24, 2022 | 1st | *Asterionella formosa* Hassall | 55.5 | *Asterionella formosa* Hassall | 75.6 | *Asterionella formosa* Hassall | 34.0 |
| | 2nd | *Fragilaria* spp. | 14.0 | *Cyclotella* spp. | 15.5 | *Cyclotella* spp. | 19.0 |
| | 3rd | *Dinobryon* spp. | 6.2 | *Cryptomonas* spp. | 4.6 | *Cryptomonas* spp. | 17.3 |
| | 4th | Unknown Chrysophyte (cyst) sp. | 5.5 | *Mallomonas* spp. | 2.0 | *Chroomonas* spp. | 13.0 |
| | 5th | *Diatoma* spp. | 4.5 | Diatoma spp. | 1.7 | *Plagioselmis nannoplanctica* (Skuja) Novarino, Lucas and Morrall | 5.3 |
| Jul 21, 2022 | 1st | *Dinobryon* spp. | 46.3 | *Dinobryon* spp. | 76.0 | *Asterionella formosa* Hassall | 27.8 |
| | 2nd | *Asterionella formosa* Hassall | 29.3 | *Fragilaria* spp. | 7.7 | *Cyclotella* spp. | 16.7 |
| | 3rd | *Ochromonas* spp. | 11.3 | *Cyclotella* spp. | 5.3 | *Cryptomonas* spp. | 15.3 |
| | 4th | *Cryptomonas* spp. | 4.7 | *Achnanthidium* spp. Kützing | 3.7 | Unknown Chrysophyte sp. | 12.5 |
| | 5th | *Chrysococcus* sp. | 3.0 | *Hannaea arcus* (Ehrenberg) Patrick | 2.3 | *Mallomonas* spp. | 9.7 |
| Aug 17, 2022 | 1st | *Aphanocapsa* spp. | 67.5 | *Aphanothece* spp. Nägeli | 44.2 | *Dinobryon* spp. | 64.6 |
| | 2nd | *Dinobryon* spp. | 13.7 | *Dinobryon* spp. | 28.6 | *Aphanothece* spp. Nägeli | 22.3 |
| | 3rd | *Chrysococcus* sp. | 10.5 | *Aphanocapsa* spp. | 11.7 | Unknown *Chrysophyte* sp. | 4.0 |
| | 4th | *Cyclotella* spp. | 5.9 | *Cyclotella* spp. | 9.8 | *Asterionella formosa* Hassall | 3.7 |
| | 5th | *Dictyosphaerium* spp. | 0.6 | *Oocystis* sp. | 2.3 | *Fragilaria* spp. | 2.2 |

Notes: Abundance is reported as a percentage, i.e., the toral number of cells of a given taxon / the total cell count for all taxa combined.
Only the five most abundant taxa are shown for each sampling date.

### 5.1.1.7 Zooplankton

Zooplankton data collected by NCCN outside of relicensing for the Little Beaver and Skymo locations are available for the period 2015-2018, and data for Pumpkin Mountain are available for 2015-2020 (data collection is ongoing outside of relicensing). Samples were collected monthly between May and November. In July 2015, one zooplankton sample was collected at the Ross Dam forebay log boom. A typical sample consisted of two replicate vertical tows.

Zooplankton density, expressed as organisms per cubic meter (org/$m^3$), was calculated for each species within each sample. Average densities for each zooplankton species were calculated between replicates. Species dominance varied over time, with total zooplankton density typically peaking in late spring and summer (Figure 5.1-17). Zooplankton densities at the Pumpkin Mountain location were overall much higher in 2019 and 2020 than during previous years.[9] In all years, maximum densities were considerably higher than densities for other samples collected during the same year (Table 5.1-9).

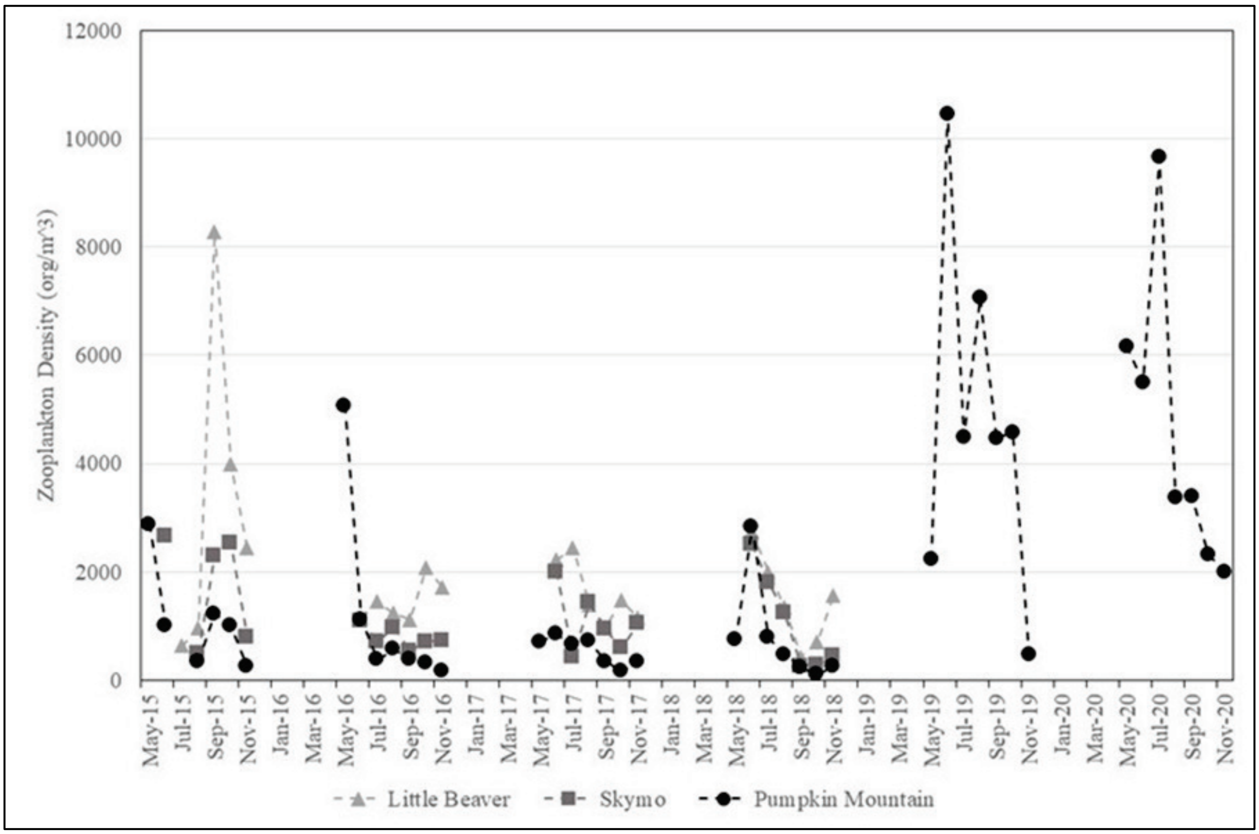



**Figure 5.1-17. Total zooplankton density (each data point is the average of two replicates) in Ross Lake (May 2015-November 2020). Source: Data collected by NCCN outside of relicensing.**

9 C. Archambault (2022) of NPS confirmed that a change to zooplankton sampling gear had been made prior to the collection of the 2019-2020 samples reported herein. A new net was deployed, which resulted in "increased ease of flow through the net." The net type, diameter, length, and mesh size did not change. It is possible that more water was actually filtered in 2019-2020, resulting in apparent, although spurious, increases in zooplankton densities.

**Table 5.1-9. Distribution statistics of zooplankton density (org/m3) in Ross Lake, by year, for all locations. Source: Data collected by NCCN outside of relicensing.**

| Percentile | 2015 | 2016 | 2017 | 2018 | 2019[1] | 2020[1] |
|---|---|---|---|---|---|---|
| Maximum | 8,290 | 5,070 | 2,447 | 2,839 | 10,459 | 9,654 |
| 75th Percentile | 2,650 | 1,234 | 1,477 | 2,002 | 5,823 | 5,827 |
| Median | 1,004 | 963 | 939 | 737 | 4,485 | 3,392 |
| 25th Percentile | 637 | 574 | 658 | 429 | 3,348 | 2,841 |
| Minimum | 103 | 160 | 163 | 100 | 466 | 1,999 |

1 2019 and 2020 data are for the Pumpkin Mountain sampling location only.

Samples were analyzed for 196 species of zooplankton. Of these 196 species, 57 species were observed at least once in the samples collected (Figure 5.1-18). Among all organisms sampled, 10 taxa[10] made up 85 percent of the organisms present, by number, ranging from 75-95 percent depending on season. The following four species made up over 60 percent of the organisms present:

- *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 and have large populations in Ross Lake. Although relative dominance of each species varied seasonally, these four species were consistently the most abundant species observed.

10 *Kellicottia longispina*, *Polyarthra vulgaris*, *Conochilus unicornis*, *Synchaeta* sp., *Bosmina longirostris*, *Daphnia rosea*, *D. pulicaria*, *Asplanchna priodonta*, Calanoida, copepod nauplii.

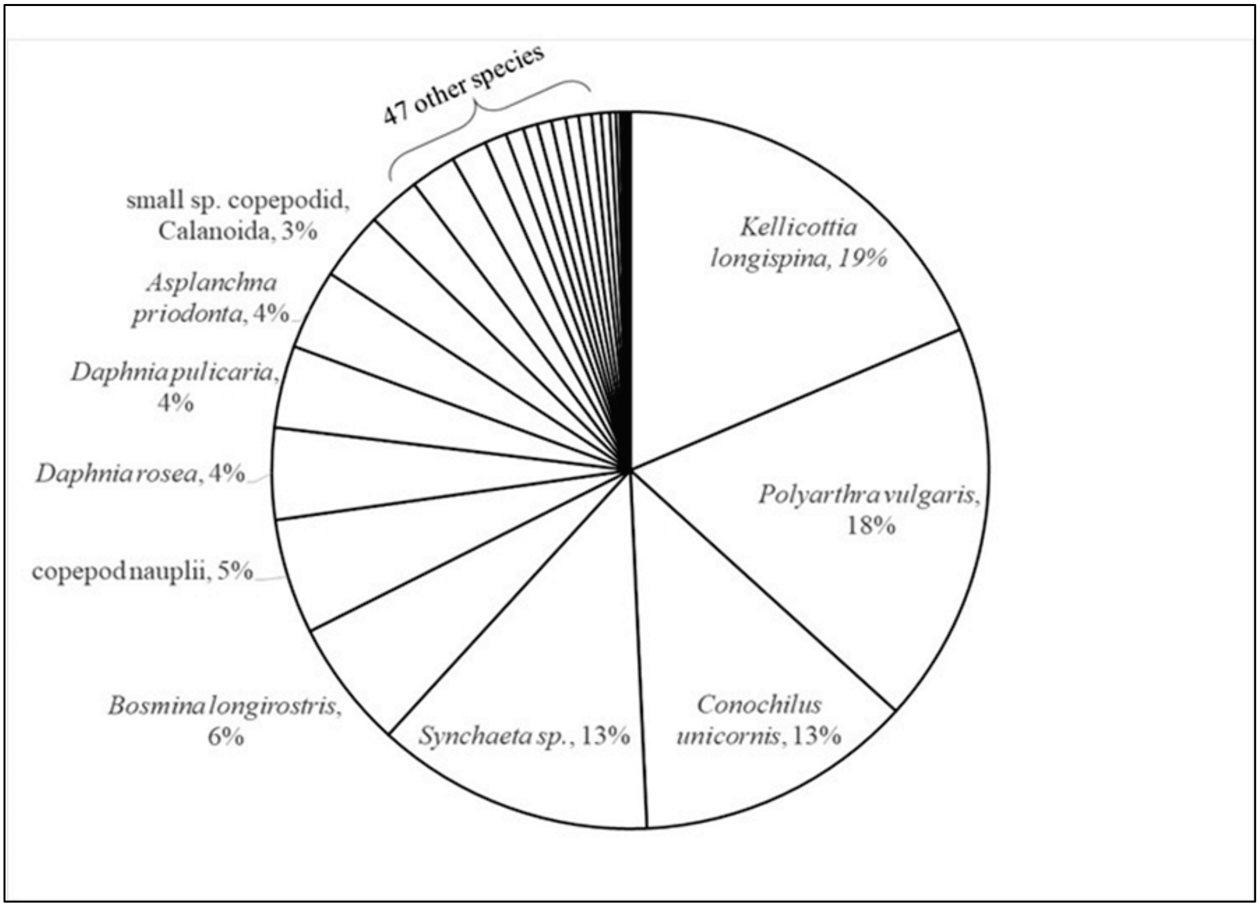



**Figure 5.1-18. Percent, by number, of total zooplankton organisms sampled in Ross Lake. Source: Data collected by NCCN outside of relicensing.**

The relative dominance of these four species varied over time, but no spatial patterns were observed. The percentages of sampled organisms identified as *K. longispina* at the Little Beaver, Skymo, and Pumpkin Mountain locations in all samples were 24.2, 23.4, and 16.4, respectively. The percentage of sampled organisms identified as *K. longispina* at all locations over time typically peaked in summer or early fall (Figure 5.1-19).

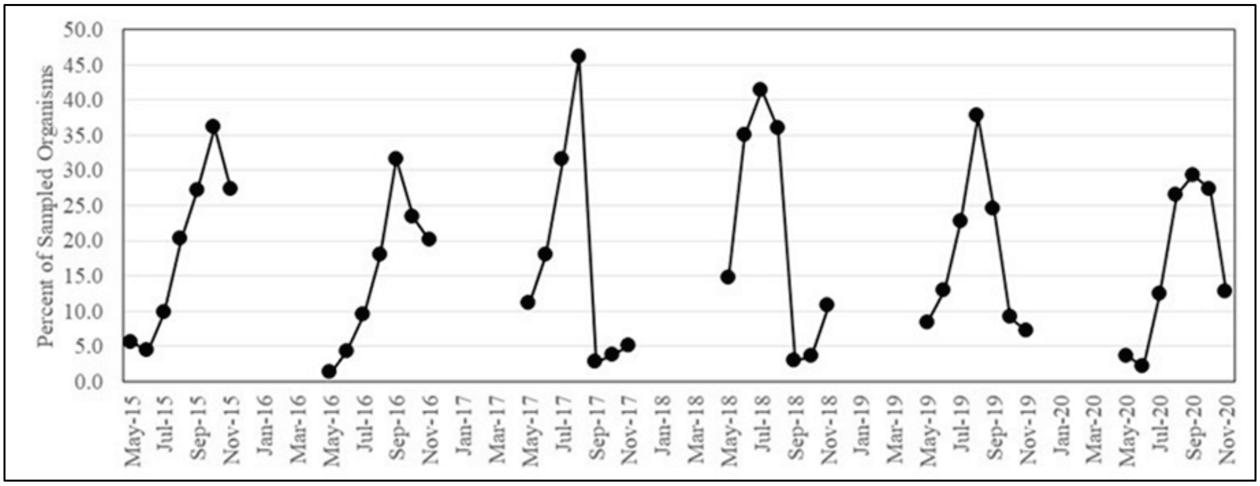



**Figure 5.1-19. Relative dominance of *Kellicottia longispina* over time. Source: Data collected by NCCN outside of relicensing.**

Similarly, the relative dominance of *P. vulgaris* did not vary considerably among locations. The percentages of sampled organisms identified as *P. vulgaris* at Little Beaver, Skymo, and Pumpkin Mountain were 19.9, 20.1, and 17.4, respectively. The percentage of sampled organisms identified as *P. vulgaris* at all locations over time reached a minimum in the summer (Figure 5.1-20).

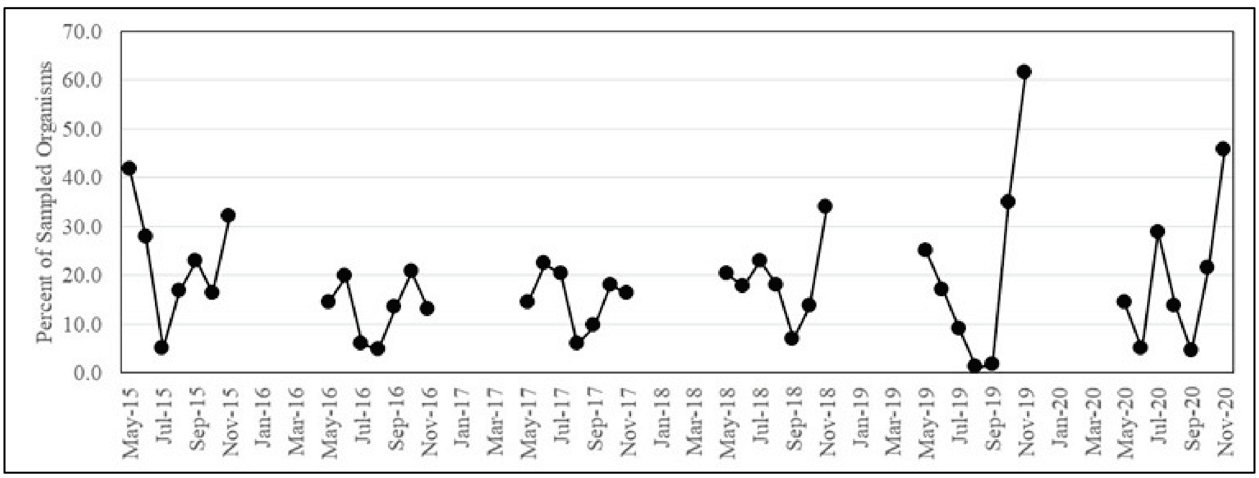



**Figure 5.1-20. Relative dominance of *Polyarthra vulgaris* over time. Source: Data collected by NCCN outside of relicensing.**

*C. unicornis* had slight variations in relative dominance among locations. The percentages of organisms identified as *C. unicornis* at Little Beaver, Skymo, and Pumpkin Mountain were 5.4, 9.8, and 14.6, respectively. The percentage of sampled organisms identified as *C. unicornis* typically peaked during the earliest sampling event each year in May, except in 2018 (Figure 5.1-21).

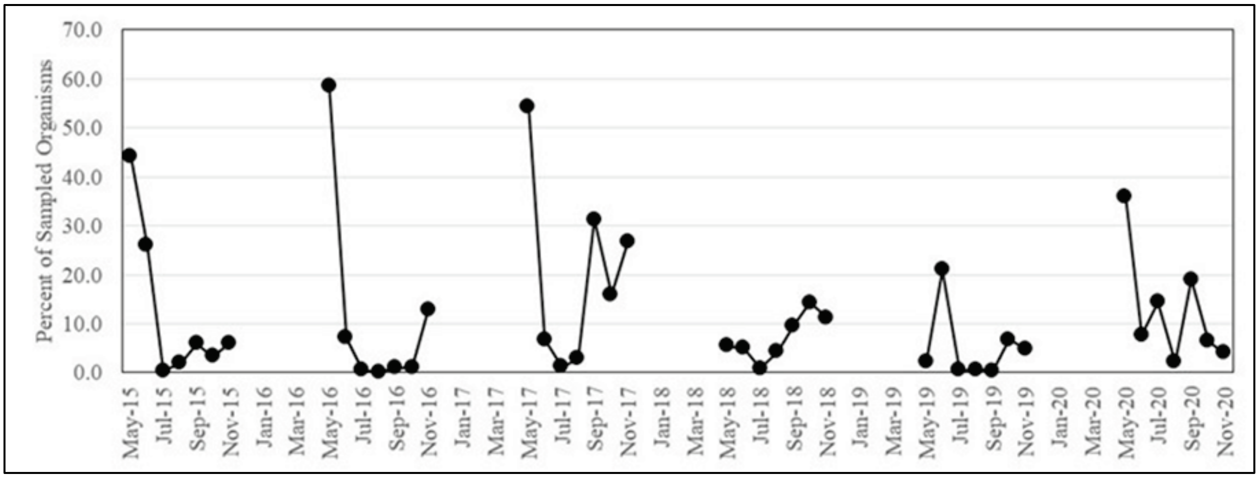



**Figure 5.1-21. Relative dominance of *C. unicornis* over time. Source: Data collected by NCCN outside of relicensing.**

*Synchaeta* sp. Also had slight variations in relative dominance among locations. The percentages of organisms identified as *Synchaeta* sp. At Little Beaver, Skymo, and Pumpkin Mountain were 4.1, 7.0, and 15.4, respectively. The percentage of sampled organisms at all locations identified as *Synchaeta* sp. Peaked in late spring and summer (Figure 5.1-22).

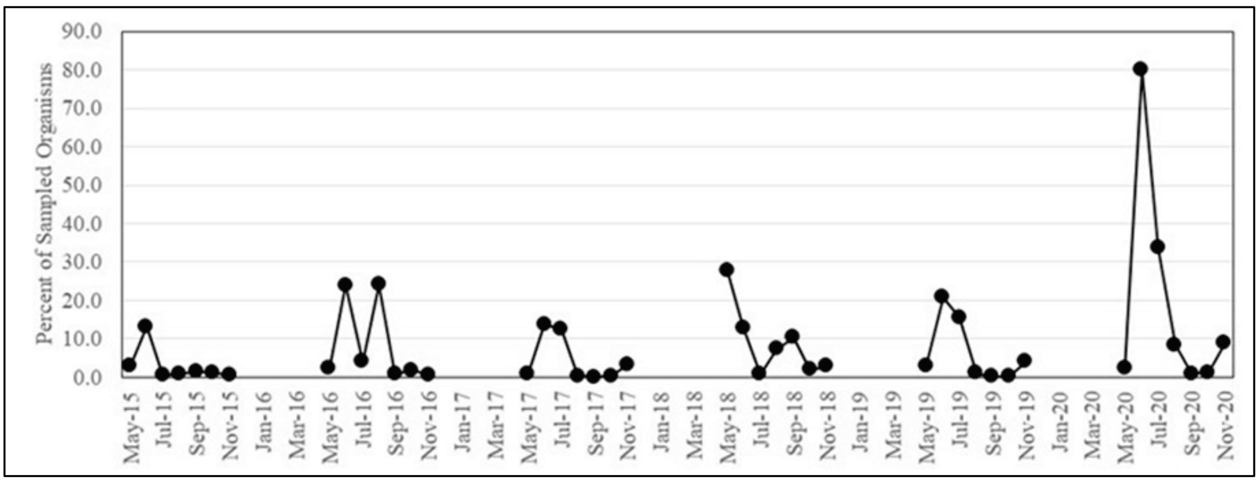



**Figure 5.1-22. Relative dominance of *Synchaeta* sp. Over time. Source: Data collected by NCCN outside of relicensing.**

#### 5.1.1.8 Benthic Macroinvertebrates

### Benthic Colonization Basket Sampling

Benthic colonization baskets were deployed to assess BMI colonization rates over time. At the time of reporting, results of benthic colonization basket sampling were only available for baskets retrieved after five weeks' submersion; sample results from baskets retrieved after 11 weeks' submersion have not been received from the taxonomy laboratory. Currently available data are insufficient to address the study question; therefore, benthic colonization basket results are not included in this report. When the full dataset is available, metrics including total abundance, taxa richness, percent EPT composition, and percent functional group composition will be analyzed.

## Reservoir Benthic Sampling

Results of PONAR sampling in Ross Lake are shown in Figures 5.1-23 through 5.1-25. At the time of reporting, results were available only for samples collected in June and September 2022; data from samples collected in October 2022 have not been received from the taxonomy laboratory. As discussed in Section 4.1.2.5, reported metrics include total abundance, taxa richness, percent EPT composition, and percent functional group composition.

In Ross Lake, total BMI abundance (number of individuals per PONAR sample) varied with site, season, and depth strata (Figure 5.1-23). Across sampling events and depth strata, cumulative abundance was highest at Desolation (747 individuals), followed by Pumpkin Mountain (369 individuals), Hozomeen (306 individuals), and Ruby Arm (26 individuals). In general, observed abundances were higher in September relative to June, and tended to decrease with depth. The highest BMI abundances were collected in September in the upper varial zone (shallowest depth, 10-20 ft), ranging from 156-637 individuals at Desolation, Pumpkin Mountain, and Hozomeen. *Bothrioneurum vejdovskyanum*, an aquatic oligochaete worm, was the dominant taxon in each of these upper varial zone samples. Observed abundances in deeper strata were similar across sites, ranging from 19-35 individuals in the lower varial zone (intermediate depth, 50-60 ft) and from 2-19 individuals in the permanently inundated zone (deepest depth, 70-80 ft). BMI abundance at Ruby Arm was consistently low in the upper varial, lower varial, and permanently inundated zones (4, 19, and 2 individuals, respectively).

Relative to September, total June BMI abundances were low at most sampling sites and strata (Figure 5.1-23). June abundances were highest at all three depth strata at Hozomeen, and in the lower varial zone at Desolation, ranging from 21-58 individuals. These samples predominantly comprised aquatic oligochaete worms (*Enchytraeidae, Lumbriculidae,* and *Sergentia sp.*). Very low or zero abundances were collected at remaining sites, including the upper varial and permanently inundated zones at Desolation (1 and 3 individuals, respectively), the lower varial and permanently inundated zones at Pumpkin Mountain (1 and 0 individuals, respectively), and in the upper varial, lower varial, and permanently inundated zones at Ruby Arm (0, 1, and 1 individuals, respectively).

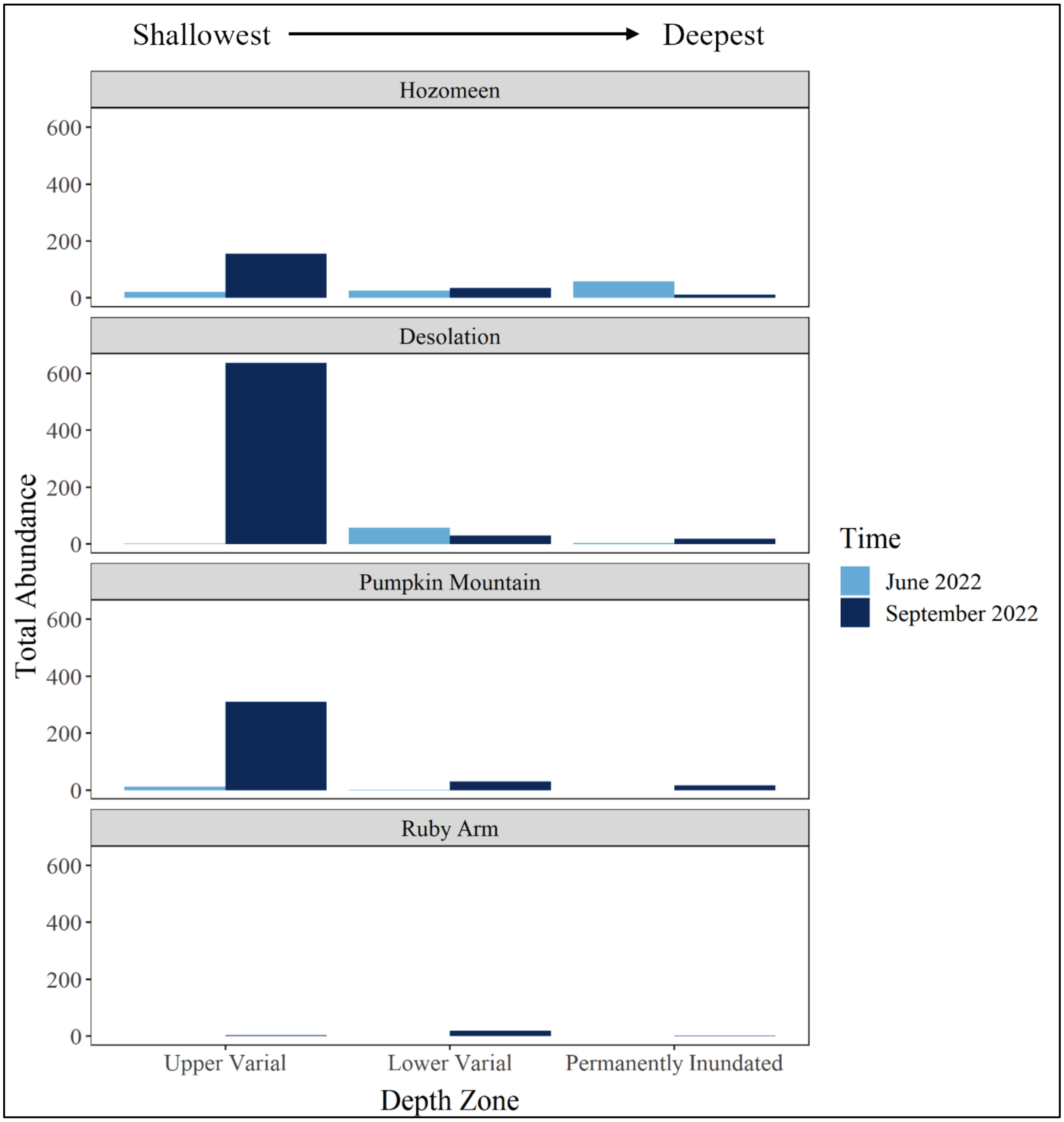



**Figure 5.1-23. BMI total abundance of PONAR samples (number of individuals per PONAR sample) collected at Hozomeen, Desolation, Pumpkin Mountain, and Ruby Arm (June and September 2022).**

Taxa richness tended to vary with depth strata, and this trend was most pronounced during the September sampling event (Figure 5.1-24). In June, Hozomeen exhibited high taxa richness across depth strata (6-7 taxa) relative to other sites, a majority of which had two or fewer taxa present. By comparison, taxa richness in September was higher and varied along a depth gradient at all locations except Ruby Arm. The upper varial zone (shallowest depth) exhibited the greatest taxa richness at Hozomeen, Desolation, and Pumpkin Mountain, ranging from 11-17 taxa. Comparatively, the lower varial zone (intermediate depth) exhibited moderate richness ranging from 7-9 taxa, while the permanently inundated zone (deepest depth) exhibited the lowest richness ranging from 4-6 taxa. At Ruby Arm, taxa richness was generally lower and more evenly distributed across the upper and lower varial zones (4 and 7 taxa, respectively), with lower richness observed in the permanently inundated zone (2 taxa).

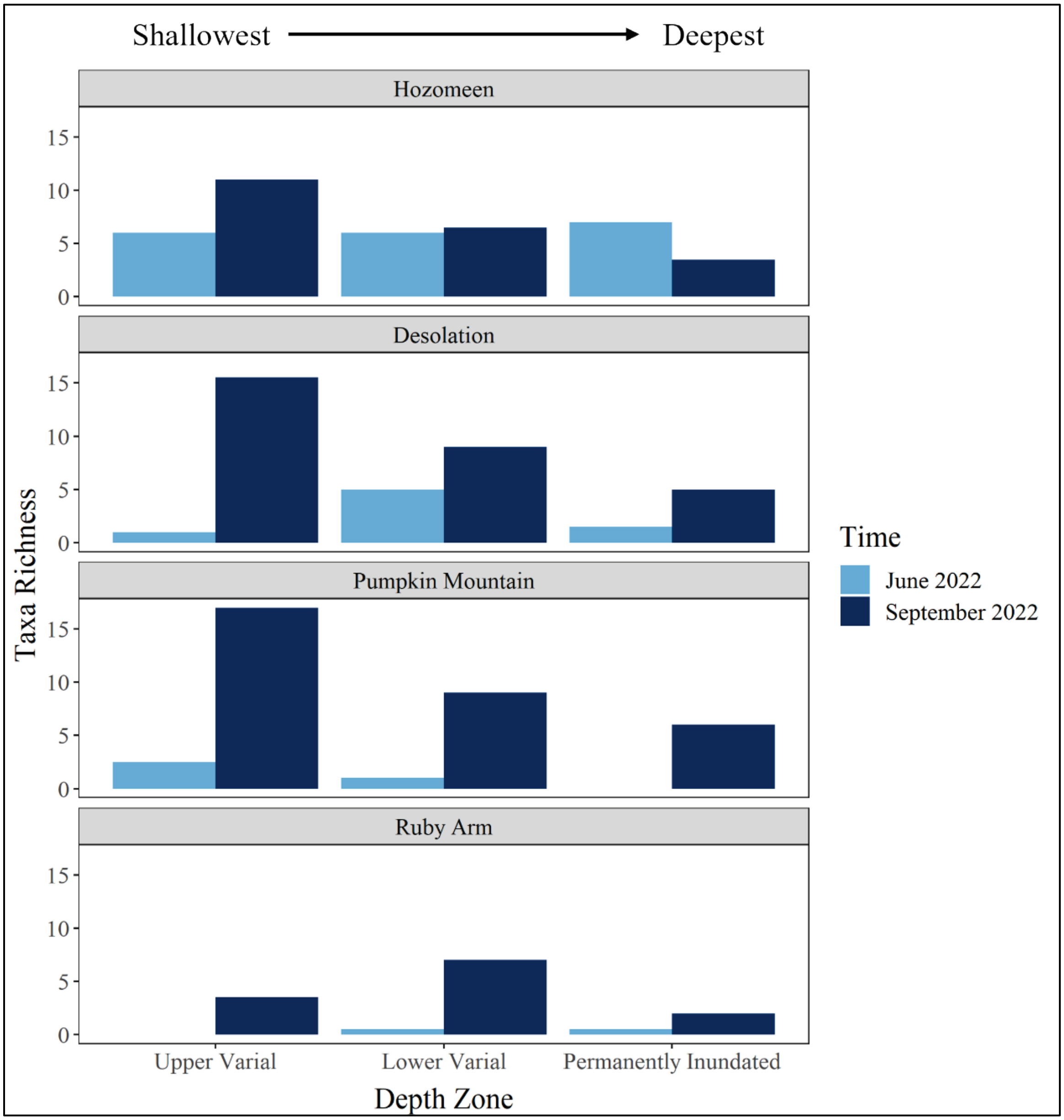



**Figure 5.1-24. BMI taxa richness of PONAR samples collected at Hozomeen, Desolation, Pumpkin Mountain, and Ruby Arm (June and September 2022).**

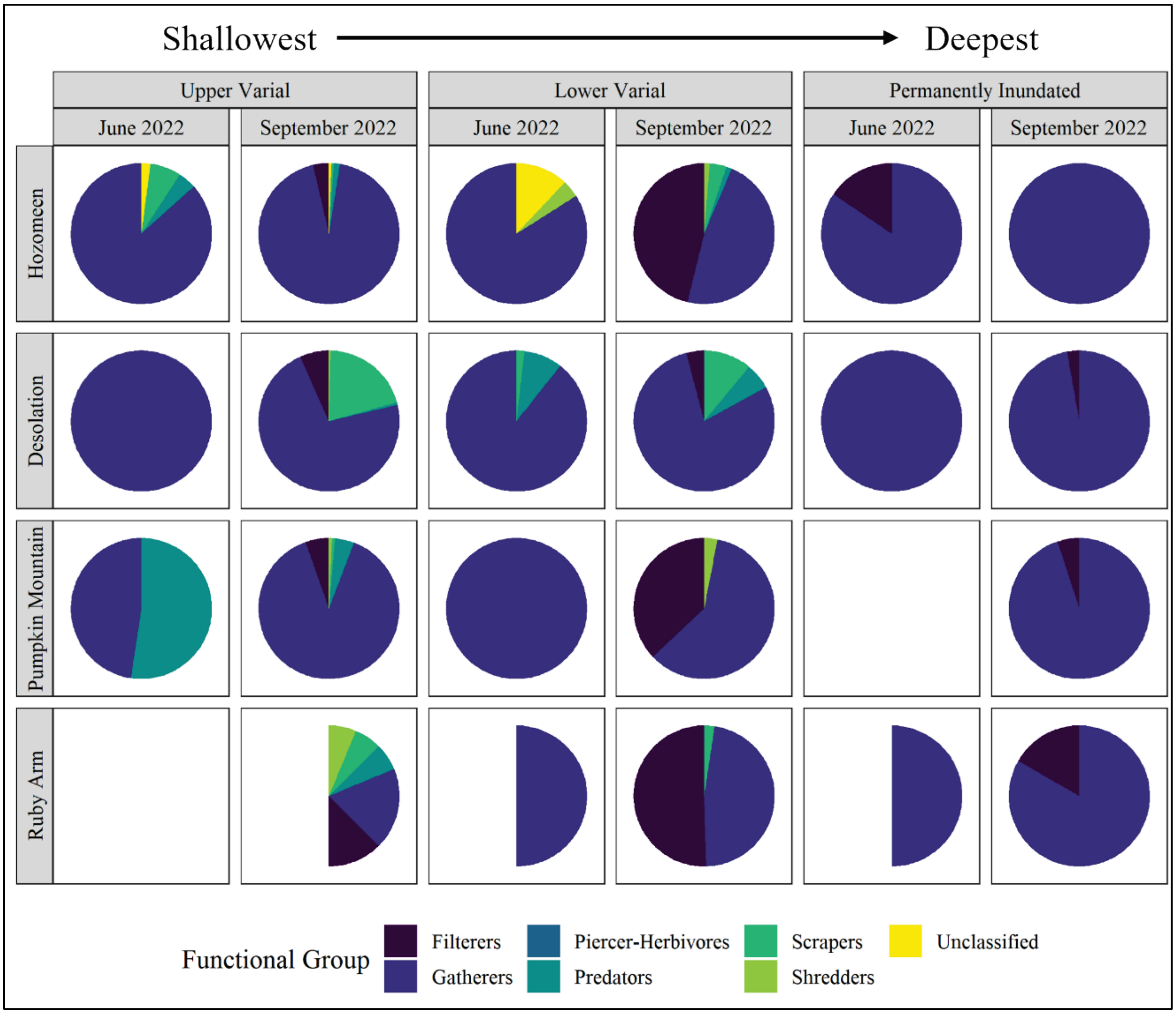
Overall, total abundance and taxa richness appeared to be lowest at Ruby Arm. A variety of physical factors (temperature, water depth, substrate type), chemical factors (nutrient concentrations, pH), biological factors (fish predators), or operational factors (annual drawdown) may contribute to this trend. One possible explanation is provided by the interaction of reservoir bathymetry with annual reservoir drawdown operations. For example, Hozomeen and Desolation littoral zones experience less sizeable fluctuations in water surface elevation and resultingly shorter periods of desiccation relative to Pumpkin Mountain and Ruby Arm (as described in FA-

03 Fish Stranding and Trapping Risk Assessment, City Light 2023b). Longer periods of littoral zone hydration at these upstream sites may support higher levels of net primary production (i.e., algal and macrophyte growth per year) required for higher order production by heterotrophic BMI communities that consume these basal resources. Differences among sites in water depth, substrate grain size, and shoreline slope may also contribute to this effect. The upstream reaches of Ross Lake are shallower, so more light may reach the bottom of the reservoir in these locations, driving up primary productivity. These reaches also generally have finer substrate and lower gradient shorelines, both of which may contribute to less desiccation during drawdown.

Total abundance and taxa richness were particularly low at Ruby Arm relative to other sites. In addition to this site's downstream location in Ross Lake, this trend likely reflects site-specific characteristics. Given the steep bathymetry and rocky substrate at Ruby Arm, it was consistently difficult to locate appropriate areas of soft sediment required for proper deployment of the PONAR grab sampler. As such, PONAR sampling was generally less effective at Ruby Arm relative to other sites, as grabs tended to sample larger sediment facies.

Percent EPT composition was low or zero across sites, depth strata, and seasons. EPT taxa were collected in just three samples, all within the reservoir varial zone. Single mayfly individuals (*Ephemerellidae* and *Caenis sp.*) were collected in June in the Desolation lower varial zone (2 percent of sample), and in September in the Pumpkin Mountain upper varial zone (less than 0.2 percent). Of all PONAR samples collected within Ross Lake, the Ruby Arm lower varial zone sample collected in September contained the greatest proportion of EPT individuals (15 percent), comprising a combination of mayfly (*Paraleptophlebia sp.*) and caddisfly individuals (*Mystacides sp.*).

Ross Lake PONAR samples indicate a BMI community dominated by gatherers, with relatively higher levels of functional group diversity observed at the upper and lower varial zones (shallow and intermediate depth strata) and during the September sampling event (Figure 5.1-25). In the upper varial zone, gatherers were abundant in June (47-100 percent) and September (72-93 percent) at Hozomeen, Desolation, and Pumpkin Mountain, but constituted a smaller percentage of Ruby Arm samples. Additional functional groups observed in the upper varial zone included predators (generally less than 7 percent, but 52 percent of the Pumpkin Mountain sample in June), scrapers (generally less than or equal to 7 percent, but 20 percent of the Desolation sample collected in September), filterers, and shredders. In the lower varial zone, gatherers were similarly dominant in both June (50-100 percent of samples) and September (47-79 percent). Filterers were absent from lower varial zone samples in June, but constituted a large proportion of Hozomeen, Pumpkin Mountain, and Ruby Arm samples in September (37-50 percent). Scrapers, predators, and shredders comprised comparatively small percentages (less than or equal to 12 percent) of lower varial zone samples. The permanently inundated zone (deepest depth) contained the least functional group diversity, with gatherers comprising a majority of all samples (83-100 percent). Filterers were the only other functional group observed in the permanently inundated zone (2-17 percent).




Note: For a given sample, functional group composition represents the mean of individual functional group percentages calculated across constituent replicate samples. Aggregate functional group composition totaling 0 percent indicates that there were no BMI individuals in either replicate (resulting in blank plots); aggregate functional group composition totaling 50 percent indicates that there were no BMI individuals in one replicate (resulting in half-circle plots).

**Figure 5.1-25. Functional group composition of PONAR samples collected at Hozomeen, Desolation, Pumpkin Mountain, and Ruby Arm (June and September 2022).**

### 5.1.1.9 QA/QC

Field and laboratory samples went through a data validation process to determine whether QA/QC requirements in the QAPP were met. Samples were flagged as estimated (J) when one or more quality control criterion was violated. These checks included evaluating whether holding time requirements were met for laboratory samples, field duplicates met the RSD criteria, and field measurements and laboratory duplicates and blanks met the accuracy criteria in the QAPP. Some of the specific QC issues identified during the data validation process are discussed below. Based on the data validation conducted for the laboratory and field data, the data are generally considered reliable and useable, with data validation qualifiers as noted in the complete electronic data record.

Warm summer air temperatures in 2021 and large sample volumes made it difficult for field personnel to meet the laboratory's recommended 4°C holding temperature during some events, even though samples were placed in coolers packed with ice per the field sampling protocols. The analytical laboratory J-flagged the August 2021 FC samples as estimated along with all samples from the first expanded analytes sampling event (May 2022) for exceeding holding temperatures. 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. Larger coolers and better coordination with the laboratory helped avoid this issue for subsequent events.

Some field duplicate pairs exceeded the 10 percent RSD criterion. In most instances where the RSD criteria were exceeded, the resulting original sample and duplicate sample concentrations were low. At low concentration, small differences between field duplicate samples can result 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).

In almost all the expanded sampling program laboratory results, laboratory analytes that were reported to be between the MDL and PQL, which means that they were detected as non-zero but below the PQL that the laboratory is authorized by Ecology to report, were flagged as J (i.e., should be considered estimated values).

Field blanks for turbidity were often reported as detects in the laboratory at very low turbidity levels. Discussion with the laboratory manager indicated that it is not uncommon for low levels of turbidity to be measured in distilled water. These samples are flagged for blank violation (with a "B" qualifier); however, the detected turbidity results from these events were considered valid as reported since the field blank violation appeared to be limited to the difficulties in discerning very low turbidity measurements in the laboratory. TSS blank violations occurred for August 2021 and June 2022; in both instances the blank TSS samples were reported as detects at or near the PQL of 2 mg/L. Similarly, there was a blank violation for the ammonium sample in May 2022 (0.02 mg/L versus PQL of 0.01 mg/L) and for the TOC samples in May and June 2022 (0.16 mg/L in May and 0.21 mg/L in June vs PQL of 0.15 mg/L). Considering the very minor detections in the blank at or close to the PQL, these exceedances were not considered to be a field contamination issue.

### 5.1.2 Diablo Lake

Monthly water temperatures measured at the log boom in the Diablo Dam forebay prior to relicensing (2014-2019) are summarized in Section 5.1.2.1. Beginning in June 2021, as part of relicensing studies, *in situ* vertical profile measurements of temperature were collected at the upper end of Diablo Lake, just downstream of Ross Powerhouse (DIABLO1) and near the Diablo Dam intake along the northern side of the forebay log boom (DIABLO2). Profiles in Diablo Lake were measured at water surface elevations ranging from approximately 1,207-1,211 ft NAVD 88 (1,201-1,205 ft CoSD). Average elevation over the 28-year period, 1991-2018, was approximately 1,208 ft NAVD 88 (1,202 ft CoSD) (City Light 2020).

#### 5.1.2.1 Temperature

At the log boom in the Diablo Dam forebay (2014-2019), monthly average surface temperatures ranged from approximately 4°C to 14°C (Figure 5.1-26). Stratification began in April, and overturn began in September. Diablo Lake's maximum depth is usually greater than 300 ft, so the deepest temperature data recorded (i.e., at 85 ft) were at an intermediate depth. Thermistor chains at other locations near Diablo Dam showed similar results (see Appendix 5 to Attachment D of the FA-01a WQ Monitoring Study Interim Report, City Light 2022a).

Temperature patterns varied among Diablo Lake tributaries (2014-2017), with greater annual variability in West Fork Creek and Fisher Creek, which had similar seasonal patterns, than in McAllister Creek (Figure 5.1-27). Insufficient temperature data were available to evaluate annual temperature variation in Thunder Creek.

Vertical profiles in Diablo Lake conducted for relicensing extend from June 2021 through September 2022. Surface water temperatures at the Ross Powerhouse boathouse (DIABLO1), increased from approximately 7°C in June to approximately 15°C in July 2021 (Figure 5.1-28). With the exception of July, water temperatures were generally isothermal at this site.

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 Dam forebay (DIABLO2), particularly in July 2021, when water temperature in the upper 2-m was 24.5°C on July 21 (Figure 5.1-28). In contrast to DIABLO1, stratification at DIABLO2 is apparent from June through September 2021, but not in October.

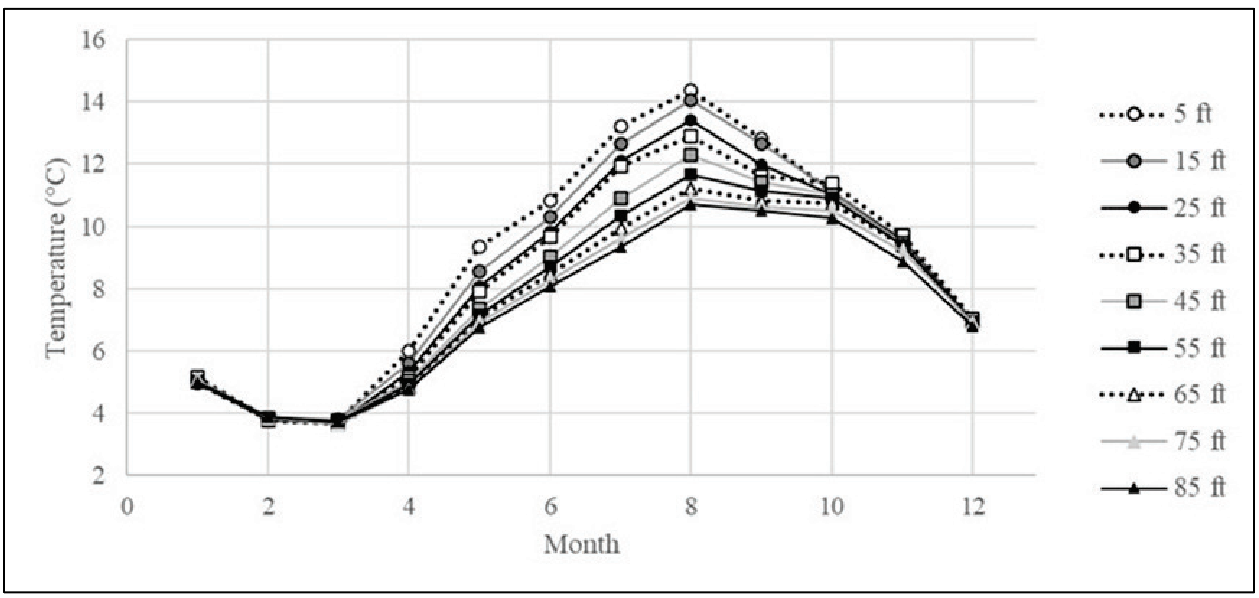



**Figure 5.1-26. Monthly average water temperature at nine depths at the log boom monitoring location in Diablo Lake (2014-2019). Source: City Light data collected outside of relicensing.**

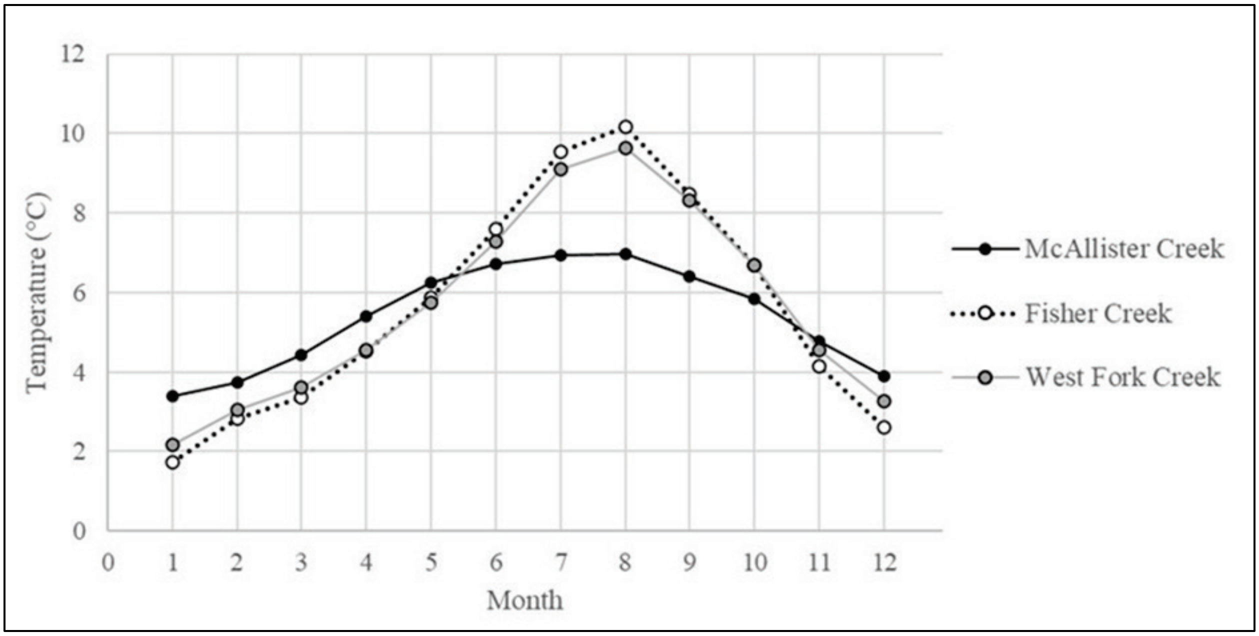



**Figure 5.1-27. Monthly averages of continuous temperature data in select tributaries to Diablo Lake: McAllister Creek (2014-2017), Fisher Creek (2014-2017), and West Fork Creek (2014-2017). Source: City Light data collected outside of relicensing.**

At DIABLO1, below Ross Powerhouse, temperatures were slightly warmer in June 2022 than in June 2021 (about 1°C). In the Diablo Dam forebay (DIABLO2), surface temperatures during June 2022 were cooler than in June 2021, around 11°C and 14°C, respectively (Figures 5.1-28 and 5.1-29). These differences reflect ambient air temperatures: June 2021 was an inordinately warm year, whereas air temperatures in spring 2022 were below average. Thermal stratification was fairly strong in the summer of 2022, particularly in August and September. In other months in 2022, thermal profiles were isothermal, or nearly so (Figure 5.1-29).

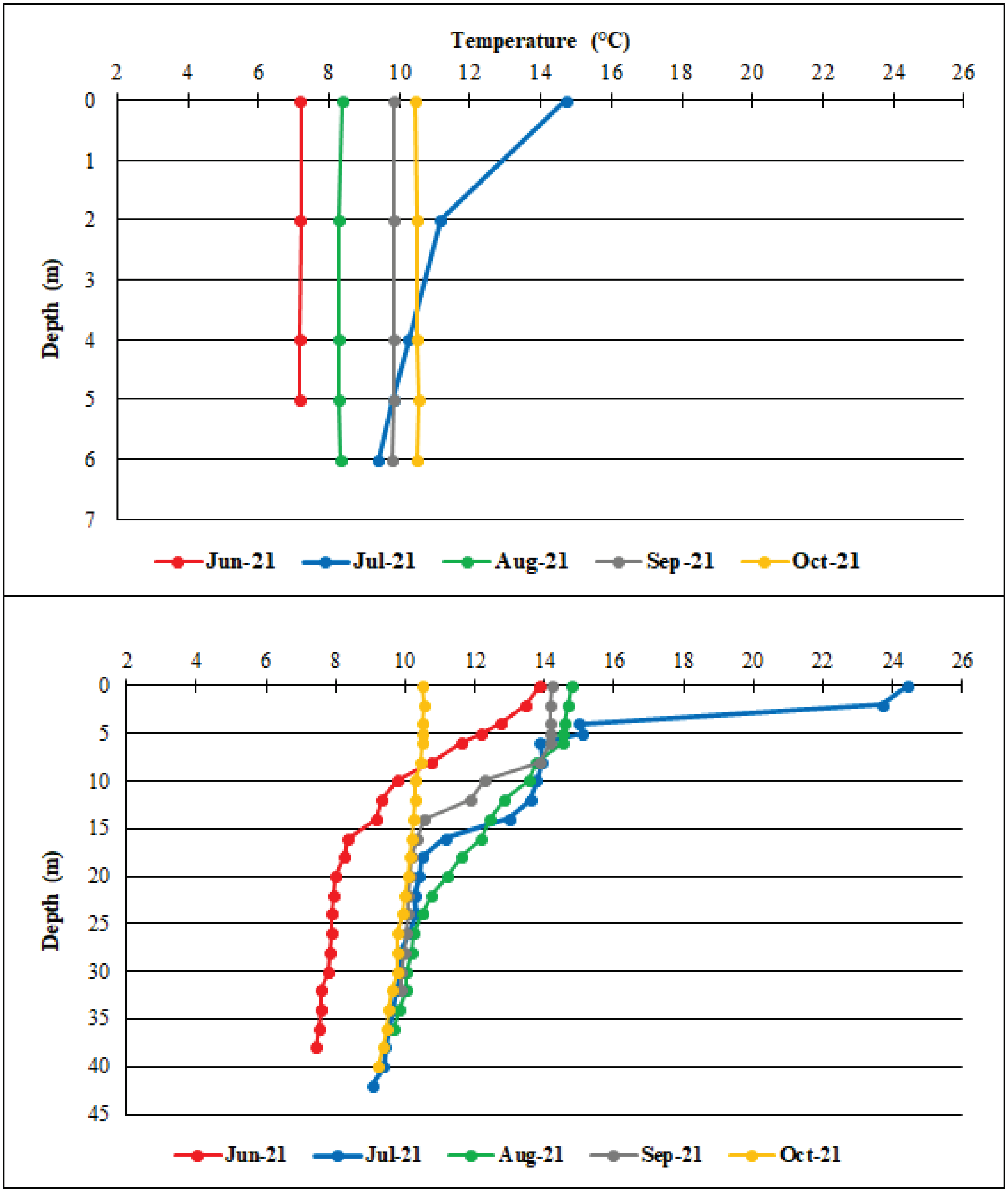



**Figure 5.1-28. Temperature profile near Ross Powerhouse (DIABLO1, top) and Diablo Dam forebay (DIABLO2, bottom) (June-October 2021).**

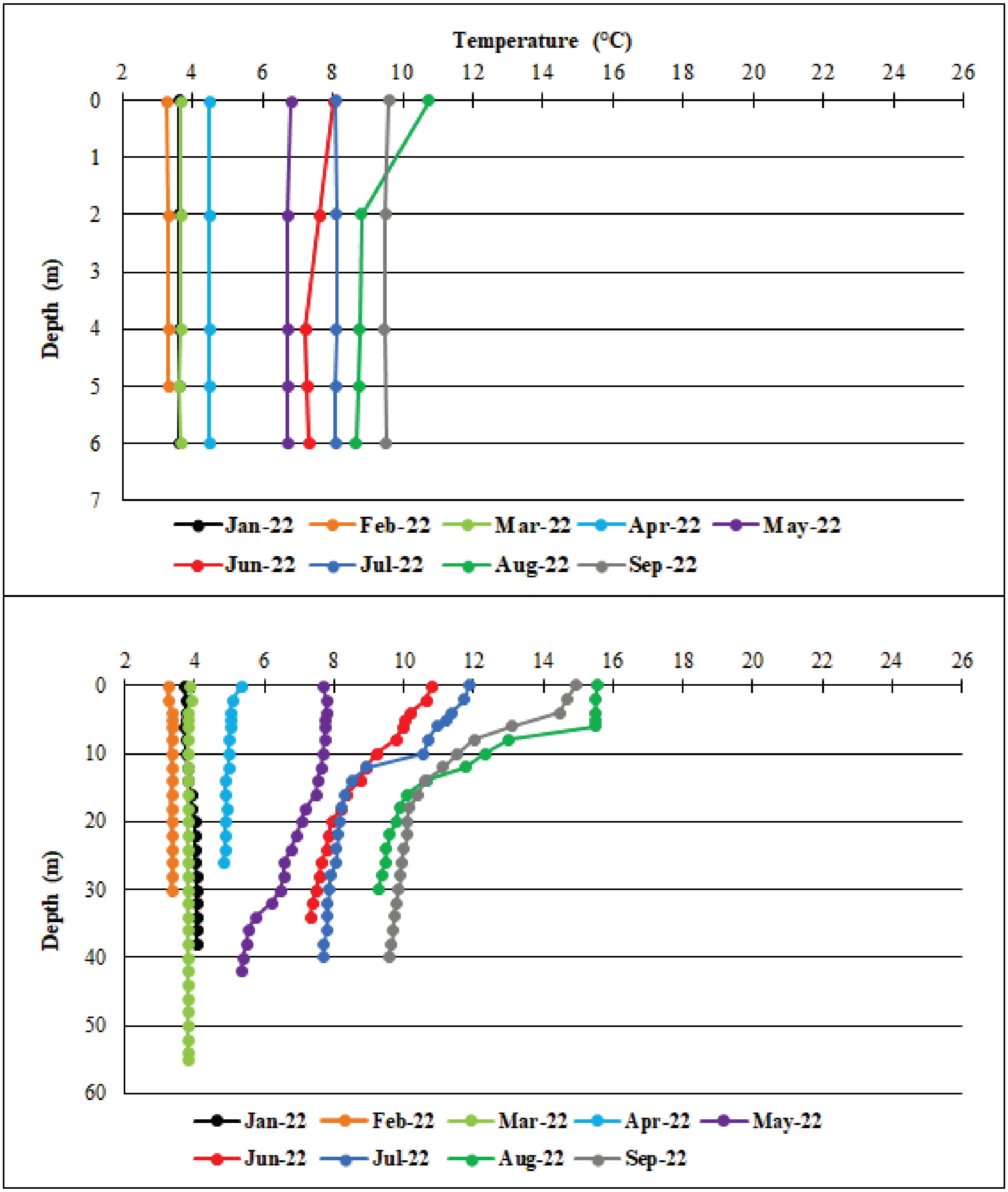



**Figure 5.1-29. Temperature profile near Ross Powerhouse (DIABLO1, top) and Diablo Dam forebay (DIABLO2, bottom) (January-September 2022).**

#### 5.1.2.2 Dissolved Oxygen

DO profiles during 2021 at the Ross Powerhouse boathouse (DIABLO1) and Diablo Dam Forebay (DIABLO2) are shown in Figure 5.1-30. 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 saturation and 118 percent saturation, respectively, based on temperatures shown above and assuming a reservoir elevation of 1,211 ft (369-m) NAVD 88 (1,205 ft [367-m] CoSD), as reported in the Pre-Application Document (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 of 2021, DO concentrations increase slightly through the mid-water column with decreasing temperatures.

Summer 2022 DO measurements at both Diablo Lake profile sites varied less than they did in 2021 (Figure 5.1-31), likely reflecting the narrower range of temperatures measured in 2022. In 2022, DO profiles at DIABLO1 ranged from 11 to 13.5 mg/L. DO profiles at DIABLO2 were similar across months in 2022, with the exception of August and September profiles that ranged from approximately 10 to 11 mg/L (Figure 5.1-31).

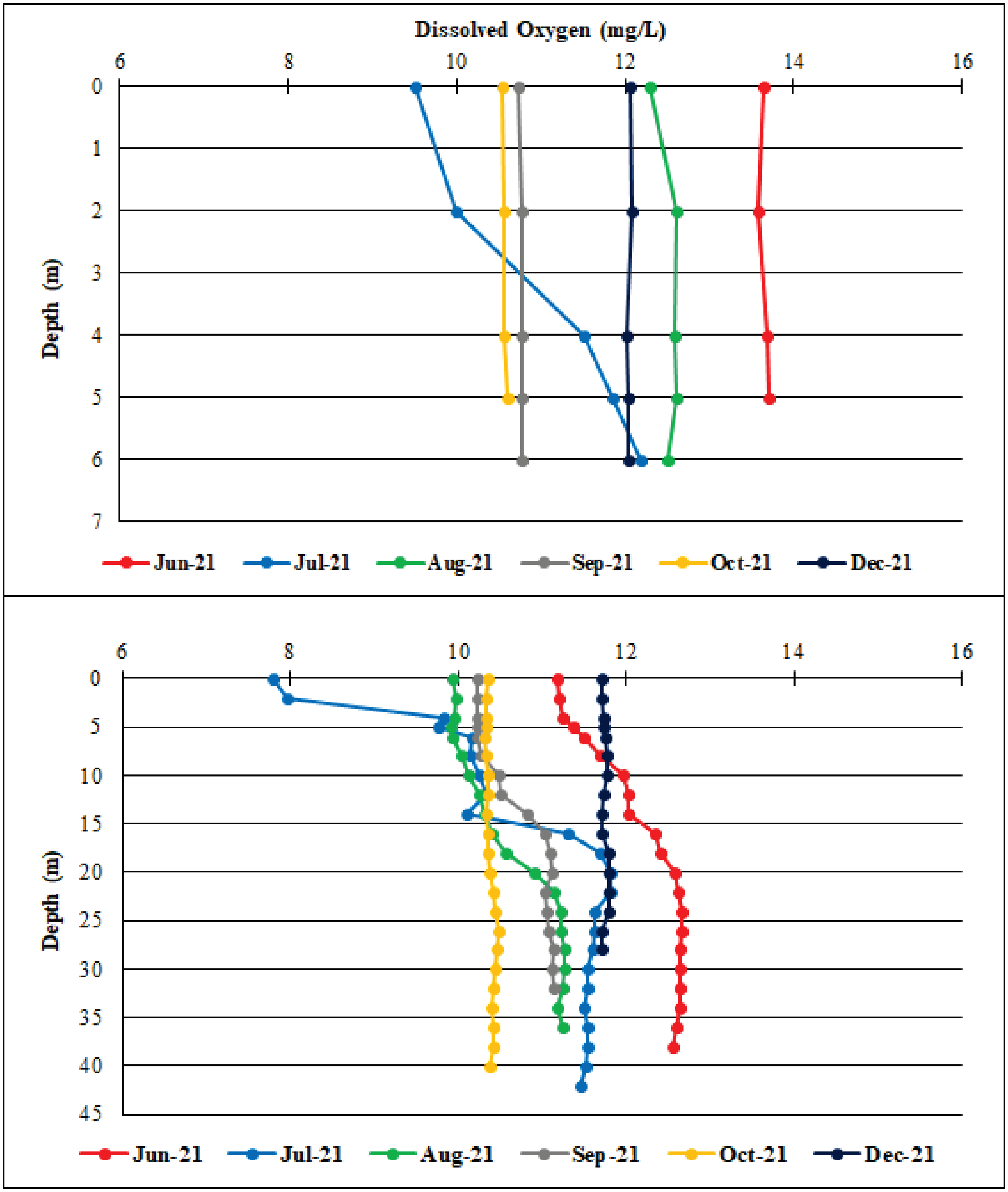



**Figure 5.1-30. Diablo Lake DO profile at Ross Powerhouse (DIABLO1, top) and the forebay (DIABLO2, bottom) (June-December 2021).**

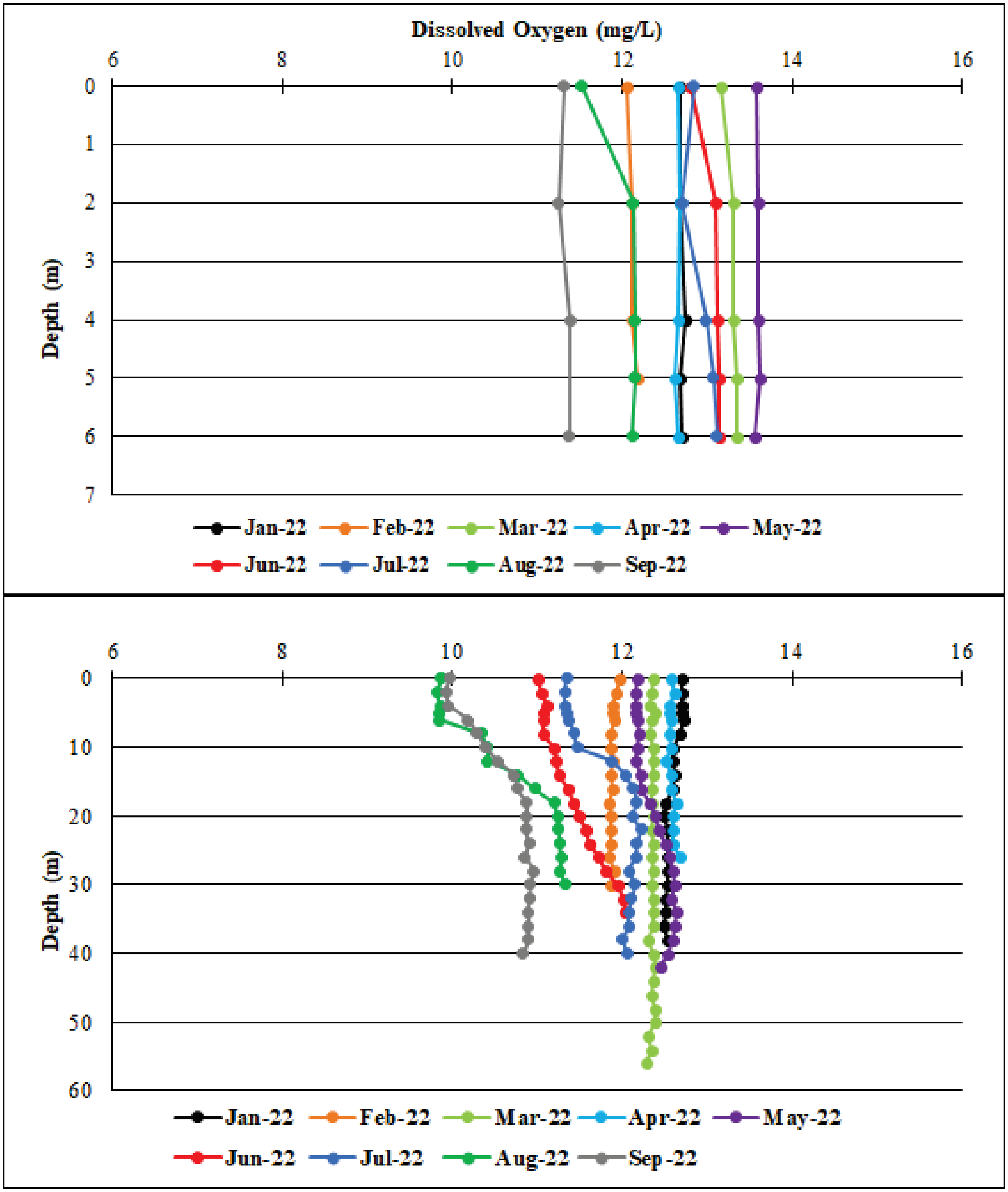



**Figure 5.1-31. Diablo Lake DO profile at Ross Powerhouse (DIABLO1, top) and the forebay (DIABLO2, bottom) (January-September 2022).**

#### 5.1.2.3 pH

pH profiles collected at the two Diablo sites are shown in Figure 5.1-32. 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. In 2022, summer pH profiles at DIABLO2 show a pronounced pH gradient in the upper 10-m; likely a result of primary production in the upper water column (Figure 5.1-33). As seen in Gorge Lake (Section 5.1.3.3) almost uniformly higher pH was seen in 2021 than in 2022, likely due to greater primary production. DO displayed an opposite pattern (generally lower in 2021 than 2022), reflecting higher water temperatures during the 2021 field season.

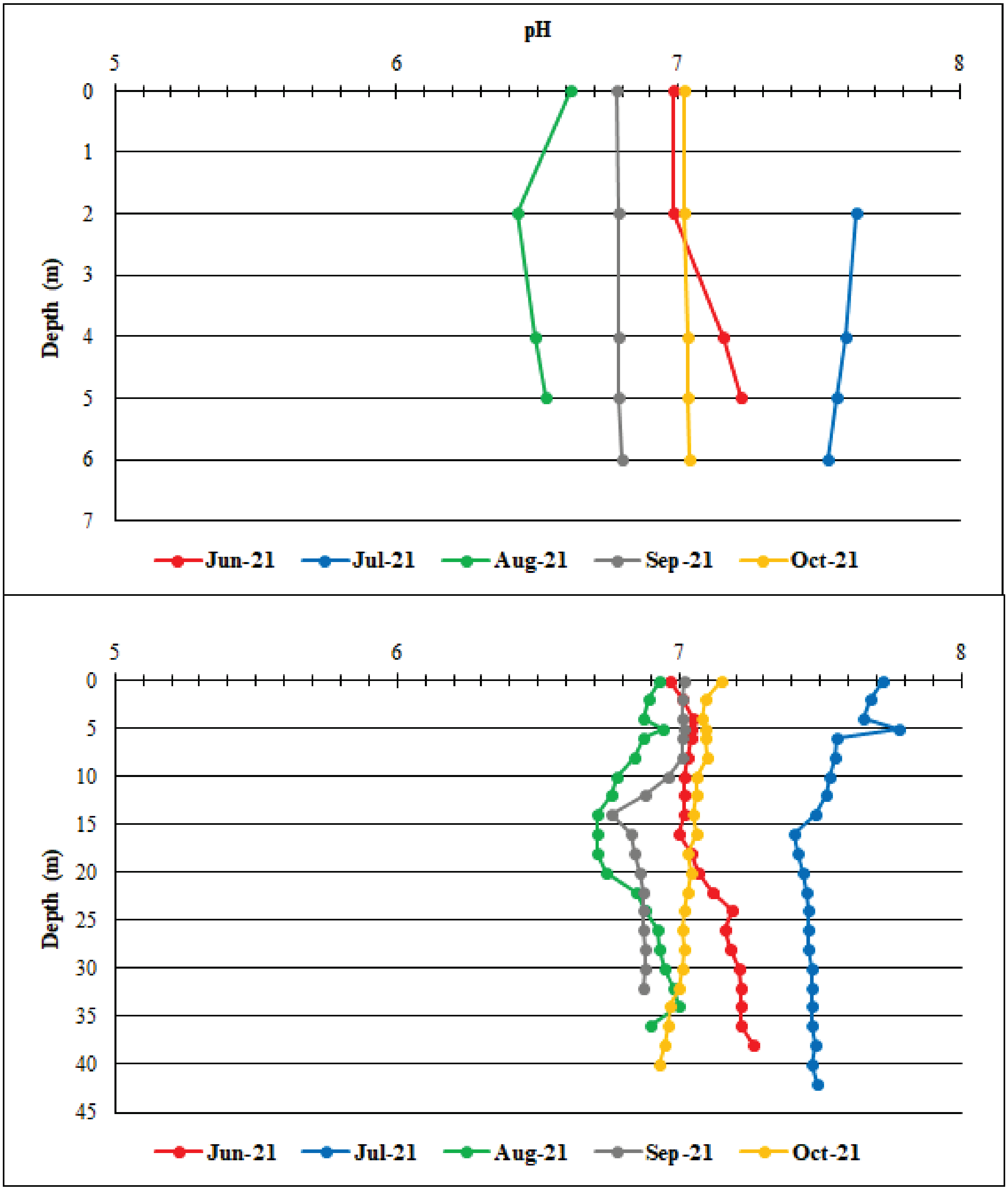



**Figure 5.1-32. pH profile at the upper end of Diablo Lake (DIABLO1, top) and the Diablo Dam forebay (DIABLO2, bottom) (June-October 2021).**

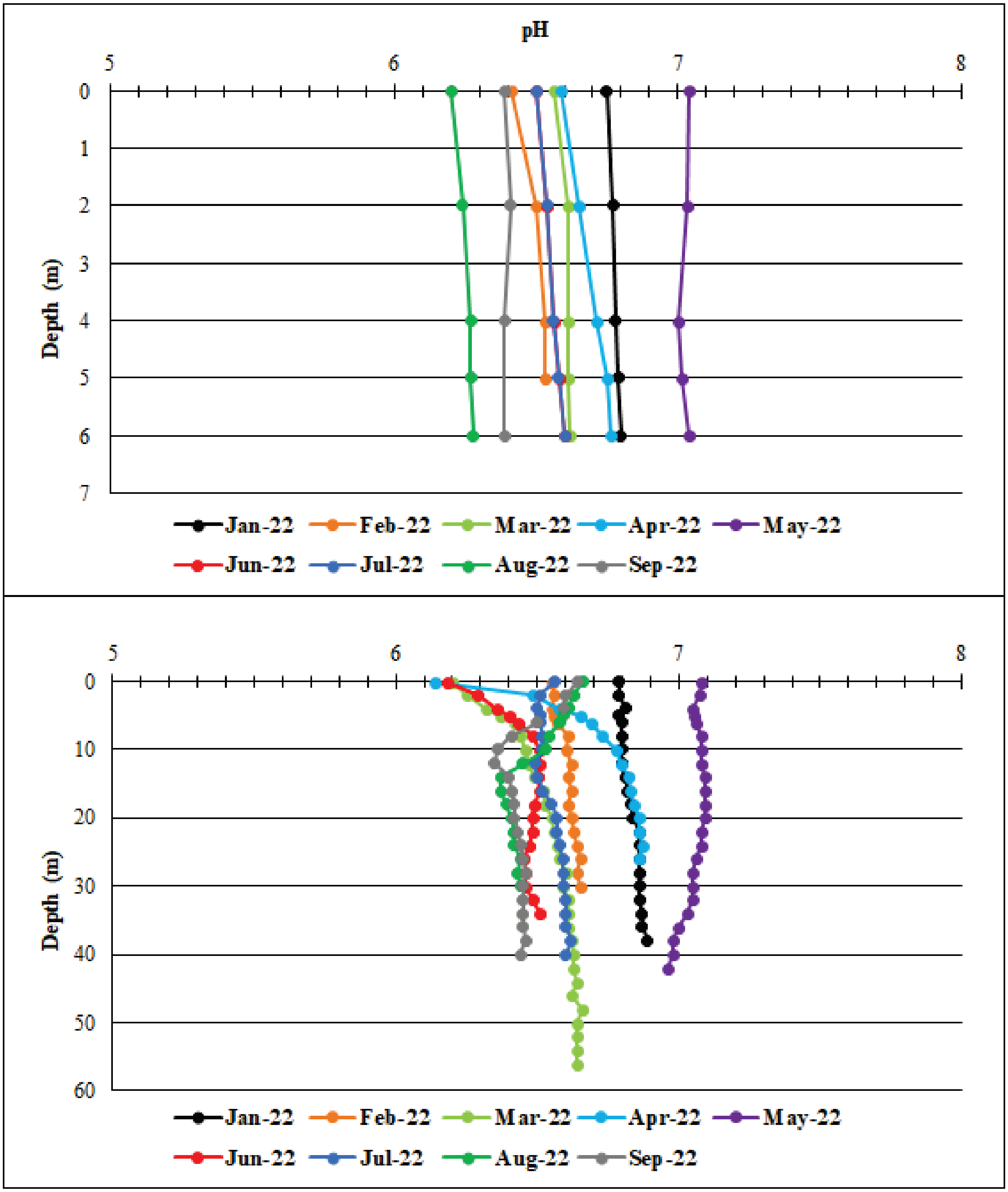



**Figure 5.1-33. pH profile at the upper end of Diablo Lake (DIABLO1, top) and the Diablo Dam forebay (DIABLO2, bottom) (January-September 2022).**

#### 5.1.2.4 Turbidity and TSS

Results of turbidity and TSS sampling at both the Ross Powerhouse Boathouse (DIABLO1) and Diablo Dam forebay (DIABLO2) are shown in Table 5.1-10. Average turbidity for the 15 monitoring events in Diablo Lake was approximately 3 NTUs at both 1- and 5-m depths, with little difference between the sites. Turbidity in Diablo Lake was higher during the winter months, reaching 14 NTUs in December 2021 at DIABLO1. With the exception of a measurement of 6.4 NTUs in June at 5-m, turbidity from June through September 2022 was less than 5 NTUs at both depths and at both sampling sites on Diablo Lake. TSS values were generally less than the 2 mg/L PQL at both sites. Maximum TSS measured at Diablo Lake was 4.5 mg/L (June 2022 at 5-m depth).

**Table 5.1-10. Turbidity and TSS at the Ross Powerhouse boathouse (DIABLO1) and Diablo Dam forebay (DIABLO2) at 1- and 5-m depths (June 2021-September 2022.**

| Date | Reservoir Elevation (ft) (NAVD 88 and CoSD) | 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-21 | 1,207 (1,200) | 3 | 2.5 | 1 | 3 | 2 | 1.7 | 2 | 2 |
| Jul-21 | 1,207 (1,200) | 1.1 | 0.71 | ND | ND | 2.9 | 3.1 | ND | 2 |
| Aug-21 | 1,209 (1,202) | 0.68 | 1.1 | ND | ND | 4.6 | 4.4 | 3 | 3 |
| Sep-21 | 1,207 (1,200) | 0.54 | 0.3 | ND | ND | 1.4 | 1.2 | ND | ND |
| Oct-21 | 1,207 (1,200) | 2.9 | 2.2 | 2 | ND | 2.9 | 3.1 | ND | ND |
| Nov-21 | *No Access* | | | | | | | | |
| Dec-21 | 1,207 (1,200) | 14 | 14 | 3 | 3 | 12 | 10 | 3 | 3 |
| Jan-22 | 1,207 (1,200) | 8.1 | 7.9 | 2 | ND | 8.3 | 8.4 | 2 | ND |
| Feb-22 | 1,208 (1,201) | 5.5 | 5.1 | ND | 2 | 5.2 | 5.6 | ND | ND |
| Mar-22 | 1,210 (1,203) | 3.1 | 2.9 | ND | ND | 2.6 | 2.9 | ND | ND |
| Apr-22 | 1,209 (1,202) | 0.75 | 0.75 | ND | ND | 0.92 | 0.8 | ND | ND |
| May-22 | 1,210 (1,203) | 0.75 | 0.69 | ND | ND | 0.71 | 0.85 | ND | ND |
| Jun-22 | 1,211 (1,204) | 4.3 | 6.4 | 3 | 4.5 | 1.2 | 2 | ND | ND |
| Jul-22 | 1,210 (1,203) | 1.9 | 1.6 | ND | ND | 3.3 | 3.4 | 2 | 2 |
| Aug-22 | 1,209 (1,202) | 0.77 | 0.71 | ND | ND | 2.1 | 2.2 | ND | ND |
| Sep-22 | 1,208 (1,201) | 0.31 | 0.41 | 2 | 2 | 1.5 | 1.5 | 2 | ND |

Notes: All elevations in the table are NAVD 88 with CoSD value in parentheses.
DIABLO1 = Upper end of Diablo Lake; DIABLO2 = Diablo Dam forebay.
Samples measured below the PQL are reported as ND. PQL for TSS is 2 mg/L for samples collected through May 2022 and 1 mg/L thereafter. PQL for turbidity is 0.1 NTU.
Sampling was not completed in November 2021 due to flooding downstream preventing access to Diablo Lake.

Results of turbidity and TSS measurements along transects in Diablo Lake are shown below (Table 5.1-11). Samples for both parameters were collected at 25-m intervals along the two 100-m transects. As shown on p. 8 of Attachment A, both transects are in the Thunder Arm of Diablo Lake. DIABLO3 is approximately center channel on the south side of the SR 20 Bridge, and DIABLO6 is parallel to and roughly 40-m from the mouth of Colonial Creek.

TSS measurements along both transects were less than the laboratory PQL for the December and March events, but all samples at DIABLO6 and one sample at DIABLO3 were above the PQL during the April event. Turbidity was less than 2.5 NTU at all sites during the sampling periods. Average turbidity for all three sampling events was less than 1 NTU along both transects, with an average of 0.45 NTUs for DIABLO3 and 0.82 NTUs for DIABLO6. A second round of transect surveys will be conducted between December 2022 and May 2023.

**Table 5.1-11. Turbidity and TSS at Thunder Arm transects (December 2021, and March and April 2022).**

| Date / Reservoir Elevation (ft) (NAVD 88 and CoSD) | Distance along Transect (m) | DIABLO3 | | DIABLO6 | |
|---|---|---|---|---|---|
| | | Turbidity (NTU) | TSS (mg/L) | Turbidity (NTU) | TSS (mg/L) |
| Dec 17, 2021 1,207 (1,200) | 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 |
| Mar 18, 2022 1,209 (1,202) | 0 | 0.32 | ND | 0.21 | ND |
| | 25 | 0.34 | ND | 1.4 | ND |
| | 50 | 0.22 | ND | 0.32 | ND |
| | 75 | 0.85 | ND | 0.77 | ND |
| | 100 | 0.39 | ND | 0.45 | ND |
| April 19, 2022 1,209 (1,202) | 0 | 0.38 | ND | 0.063 | 3 |
| | 25 | 0.39 | ND | 1.1 | 6 |
| | 50 | NM | NM | 1.4 | 4 |
| | 75 | 0.26 | ND | 2.3 | 16 |
| | 100 | 0.32 | 2 | 0.22 | 2.5 |

Notes: All elevations in the table are NAVD 88 with CoSD value in parentheses.
NM=not measured, ND=not detectable (less than PQL, which is 2 mg/L for TSS and 0.1 NTU for turbidity).
DIABLO3 = Thunder Creek Confluence at Bridge/Colonial Creek Campground at Rhode Creek.
DIABLO6 = Thunder Creek Confluence at Bridge/Colonial Creek Confluence.

A Secchi disk was used to measure water transparency in Diablo Lake during vertical profile measurement periods. Secchi depth ranged from a minimum of about 1.5-m at both sites to a maximum of about 6-m (bottom) at DIABLO1 in September, and about 7-m at DIABLO2 in May prior to snow melt (Figure 5.1-34).

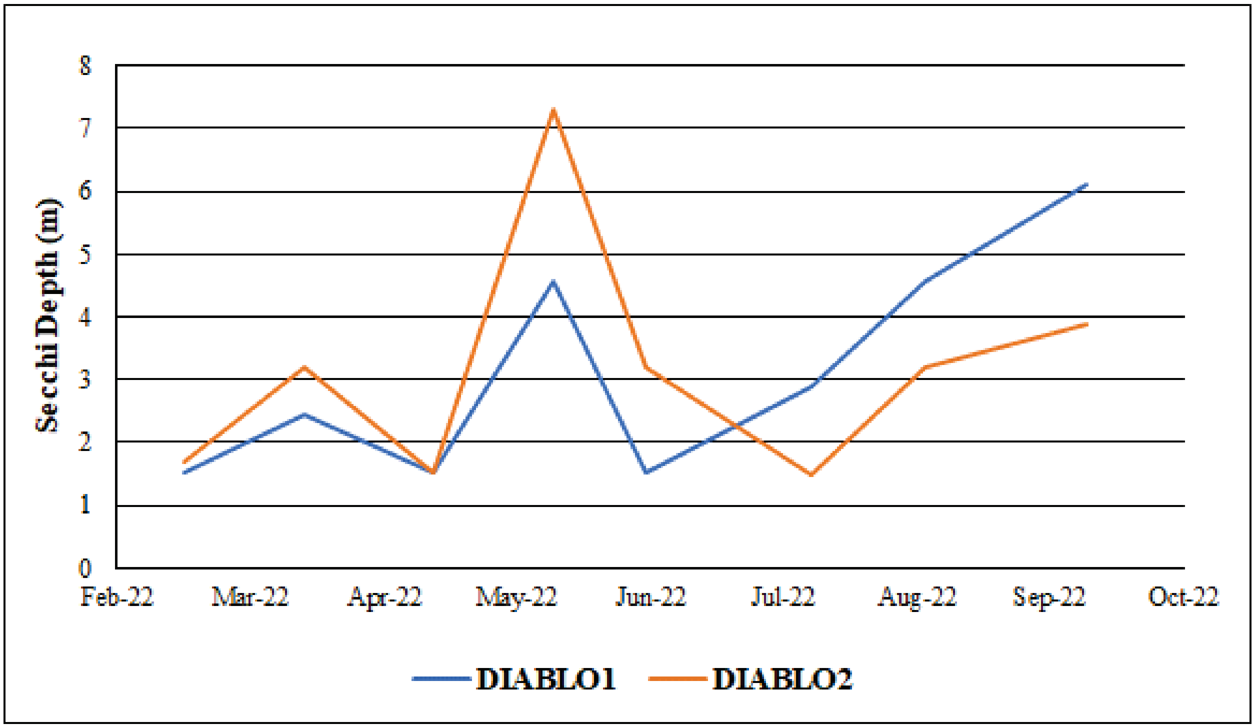



**Figure 5.1-34. Water transparency as measured with a Secchi disk in Diablo Lake (February-September 2022).**

5.1.2.5 Fecal coliform/*E. Coli*

Results of bacterial analyses at Diablo Lake are shown in Table 5.1-12. Maximum FC concentrations were reported in June 2021 at DIABLO4 (104 CFU/100 mL), although concentrations were 52 CFU/100 mL in June 23021 qat DIABLO5. At DIABLO4, measurements of both FC and *E. coli* were also detectable in August 2021 and for all samples collected in 2022, but these levels were generally low except for the FC sample in September. Bacterial levels were largely non-detect at DIABLO5. Overall, the bacterial levels met the state standard for primary contact recreation of 100 CFU/100 mL or less (as a geometric mean when more than 3 samples are available), with not more than 10 percent (or any single sample when less than 10 samples exist for a site) obtained within the averaging period exceeding 320 CFU/100 mL. The FC geometric mean for 2021 and 2022 at DIABLO4 was 8.8 CFU/100 mL and 5.98 CFU/100 mL, respectively. The geometric mean of *E. coli* in 2022 at DIABLO4 was 1 CFU/100 mL (with non-detects set to 1 CFU/100 mL).

**Table 5.1-12. Diablo Lake monthly FC and E. coli sampling results (June-September, 2021 and 2022).**

| Date | DIABLO4 | | DIABLO5 | |
|---|---|---|---|---|
| | FC (CFU/100 mL) | *E. coli* (CFU/100 mL) | FC (CFU/100 mL) | *E. coli* (CFU/100 mL) |
| Jun 30, 2021 | 104 | - | 52 | - |
| Jul 26, 2021 | ND | - | ND | - |
| Aug 17, 2021 | - | - | ND | - |
| Aug 20, 2021 | 13 (15) | 11 | - | - |
| Sep 14, 2021 | ND | ND | 2 | 2 |
| Jun 21, 2022 | 2 | 1 | ND | ND |
| Jul 19, 2022 | 5 | 5 | ND | ND |
| Aug 18, 2022 | 4 | 3 | 1 | 1 |
| Sep 28, 2022 | 32 | 8 | ND | ND |

Notes: DIABLO4 = Thunder Creek Confluence at Bridge/Colonial Creek Campground.
DIABLO5 = Environmental Learning Center.
Samples measured below the PQL (2 CFU/100 mL) are reported as ND.
Field duplicate results are shown in parenthesis. Sampling events included Ross and Diablo lakes, and duplicate results are also shown in Table 5.1-6.
*E. coli* was only measured at DIABLO4 in August 2021, and at both sites starting in September 2021.

### 5.1.2.6 Nutrients and Productivity

#### Nutrients and Chlorophyll *a*

As part of its expanded scope of water quality monitoring (Table 4.1-1), City Light has undertaken nutrient and productivity sampling in the forebay of Diablo Lake (DIABLO2) and at the mouth of Thunder Creek. Samples were collected in the reservoir's forebay at three depths to represent the epilimnion, metalimnion, and hypolimnion.

Figures 5.1-35a and 5.1-35b show nutrient and chlorophyll *a* concentrations at DIABLO2 in 2022, and Figures 5.1-36a and 5.1-36b show the corresponding values at the mouth of Thunder Creek. All phosphorus and TKN measurements, and nearly all of the ammonium ($NH_4$) and chlorophyll *a* samples, were at or below the PQL. Nitrate+nitrite ($NO_x$) was detected frequently, albeit at low levels. The hypolimnion samples showed the highest nitrate concentrations over the summer period of thermal stratification, indicating accumulation of nutrients either from sediment recycling or from tributary inflow that does not diffuse upward into the epilimnion. Similarly, at the Thunder Creek mouth, incoming ammonium and orthophosphate were largely below the PQL, but nitrate samples were also observed to be largely at the PQL. Chlorophyll *a* remained lower than the oligotrophic indicator of 0.94 µg/L (Carlson 1977) throughout the sampling period (May through September) in the Diablo Dam forebay epilimnion (DIABLO2). The observed low nutrient and chlorophyll *a* levels are consistent with previous monitoring results, which indicate that the Project reservoirs and their tributaries constitute an oligotrophic system.

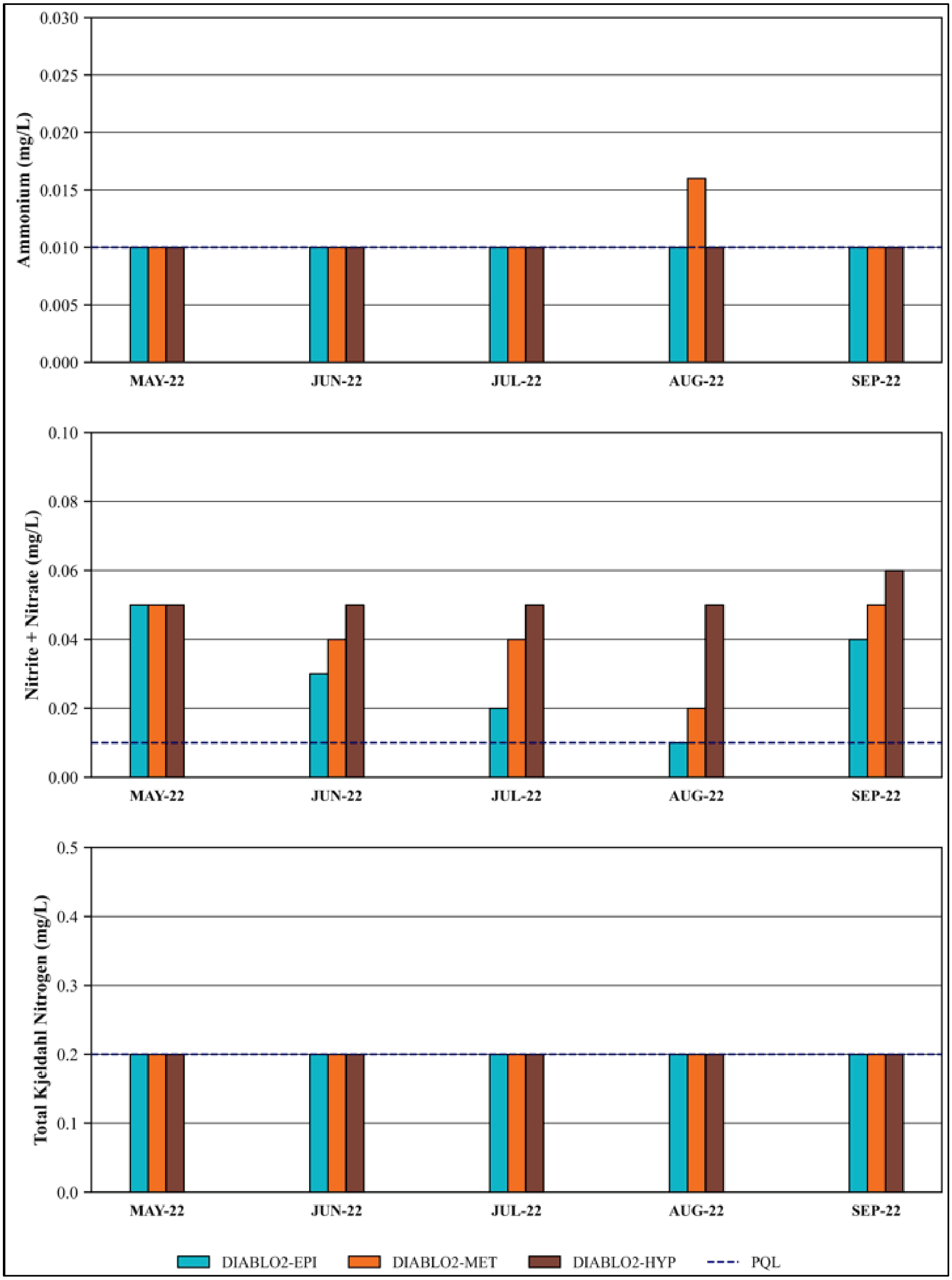



**Figure 5.1-35a. Nitrogen concentrations in Diablo Dam forebay (DIABLO2), epilimnion, metalimnion, and hypolimnion (2022); PQL = practical quantitation limit.**

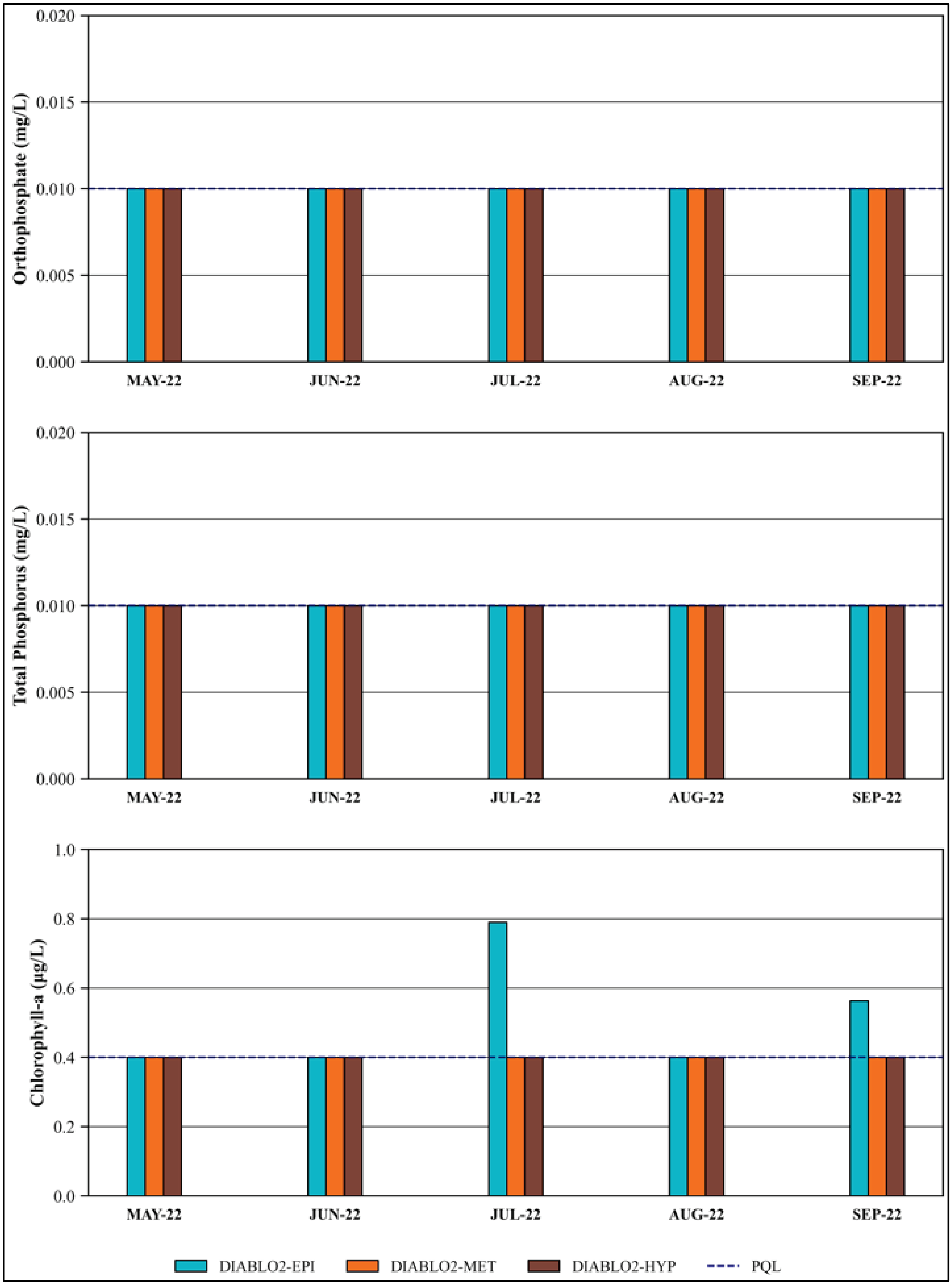



**Figure 5.1-35b. Phosphorus concentrations and chlorophyll *a* in Diablo Dam forebay (DIABLO2) epilimnion, metalimnion, and hypolimnion (2022); PQL = practical quantitation limit.**

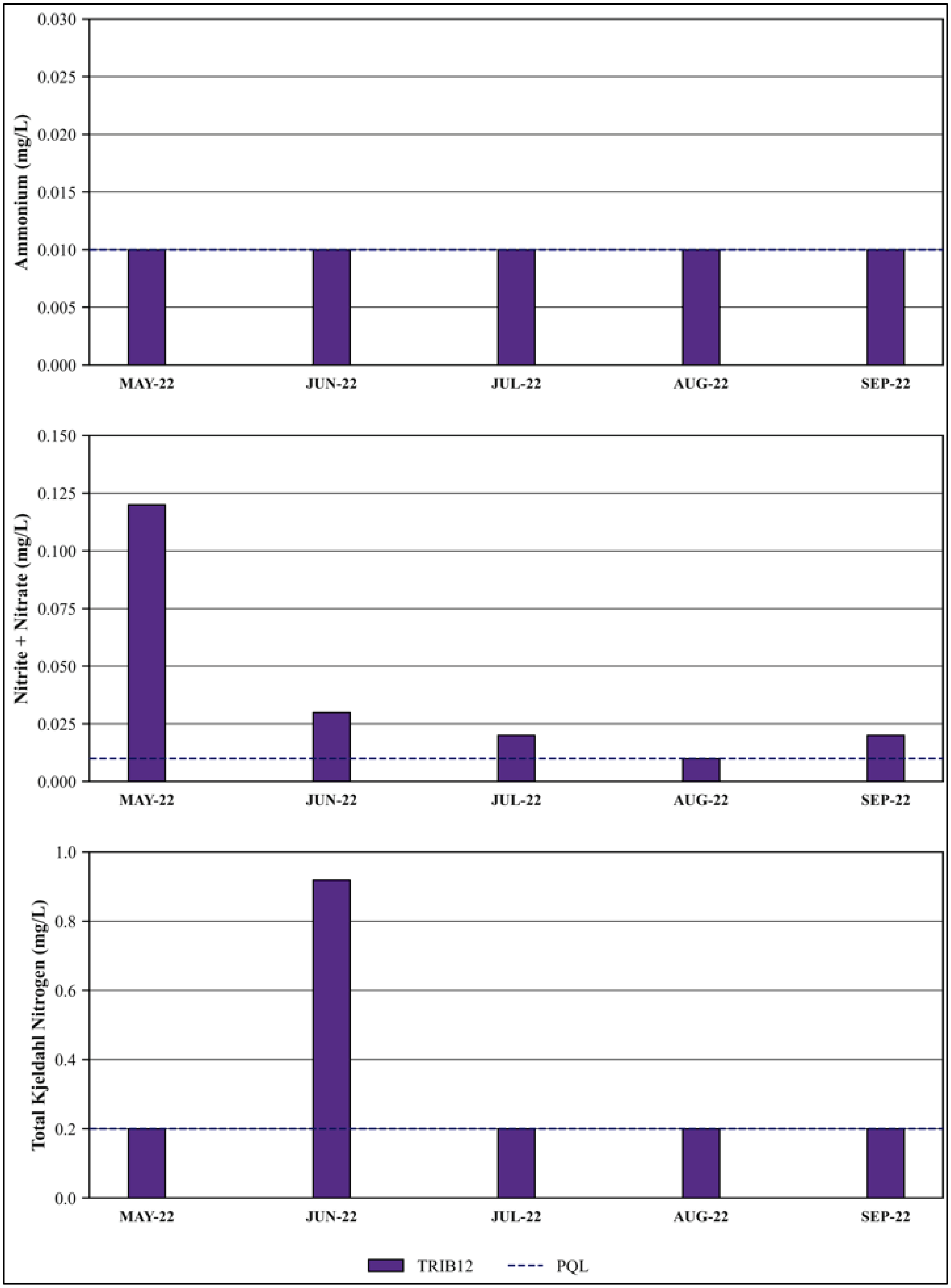



**Figure 5.1-36a. Nitrogen concentrations in Thunder Creek (TRIB12) (2022); PQL = practical quantitation limit.**

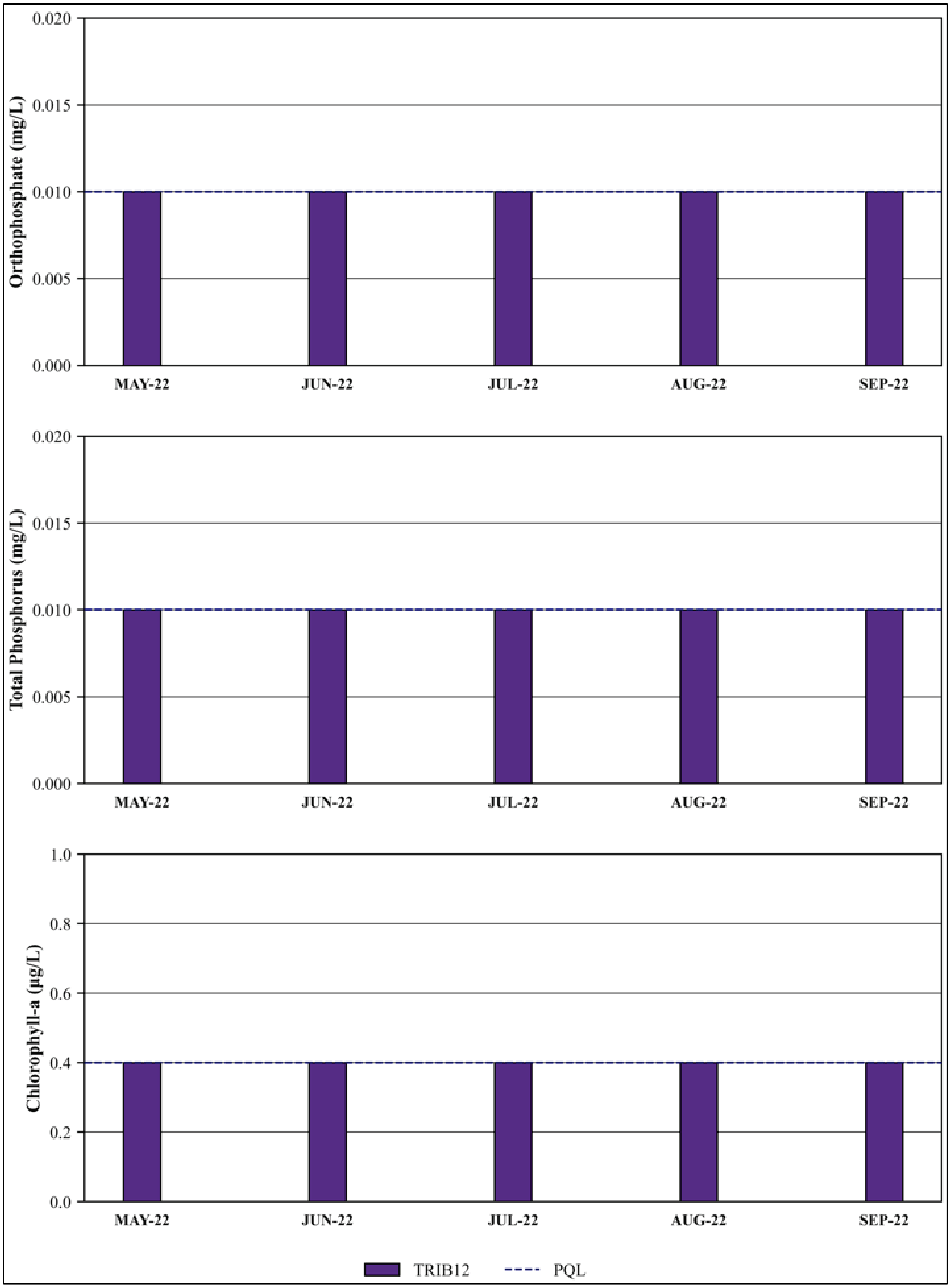



**Figure 5.1-36b. Phosphorus concentrations and chlorophyll *a* in Thunder Creek (TRIB12) (2022); PQL = practical quantitation limit.**

### Organic Carbon and CBOD

Levels of organic carbon and CBOD in the Diablo Dam forebay (DIABLO2) and Thunder Creek (TRIB12) from May through September 2022 are shown in Figures 5.1-37 and 5.1-38, respectively. Organic carbon concentrations (dissolved and particulate) were generally low (less than or equal to 1 mg/L) in Diablo Lake and at Thunder Creek, which indicates low productivity within the system.

### Total Inorganic Carbon and Alkalinity

TIC and alkalinity in Diablo Dam forebay (DIABLO2) and Thunder Creek (TRIB12) are shown in Figures 5.1-39 and 5.1-40, respectively. Unusually high alkalinity occurred in the epilimnion of Diablo Lake during September, which is inconsistent with the TIC levels that were relatively consistent at all forebay depths during the same period and in the Thunder Creek inflow (Figure 5.1-40), and in Ross Lake (see Section 5.1.1.5). Over this same period there was no apparent evidence of high primary productivity in the reservoir (Figure 5.1-35b).

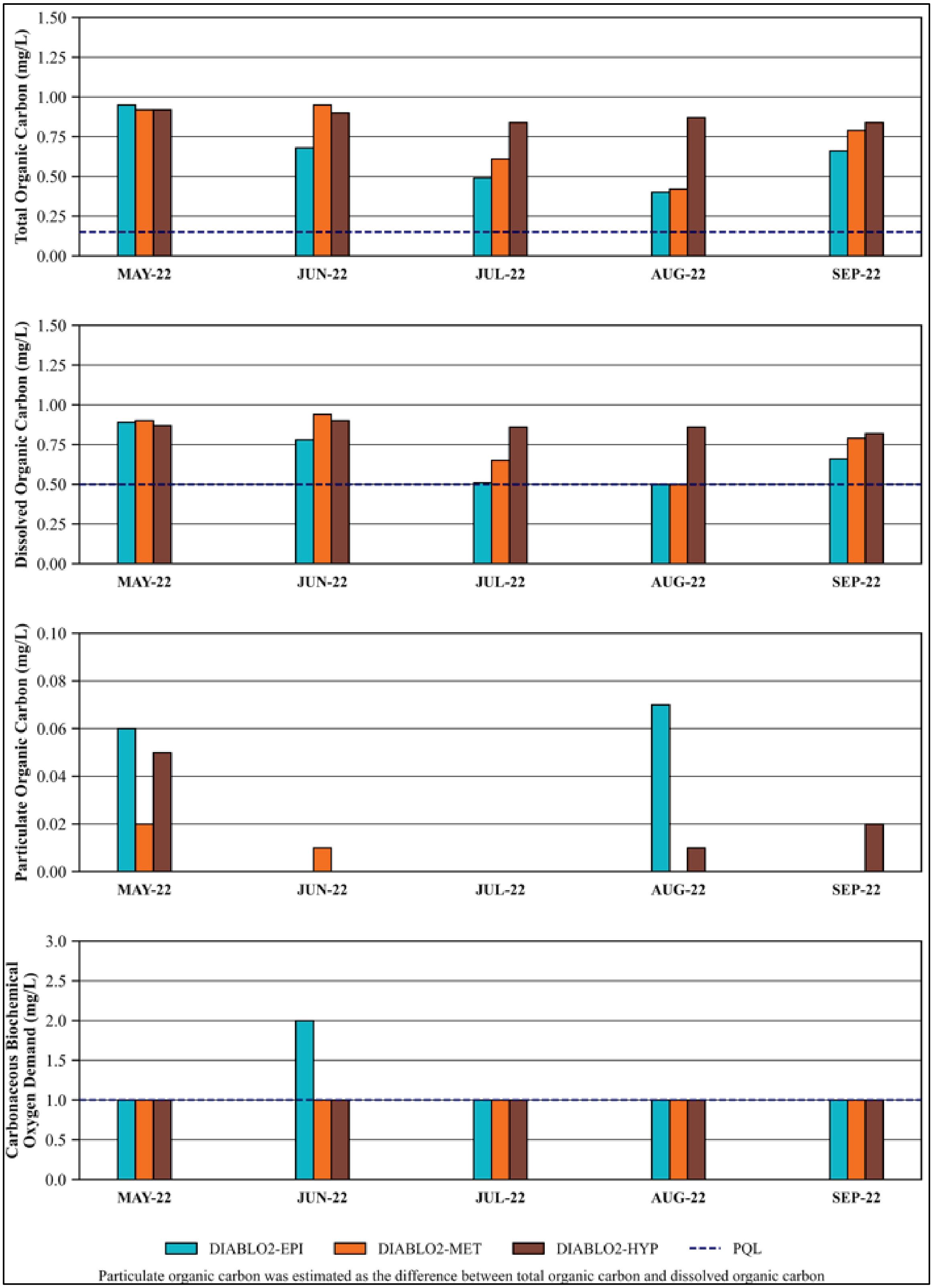
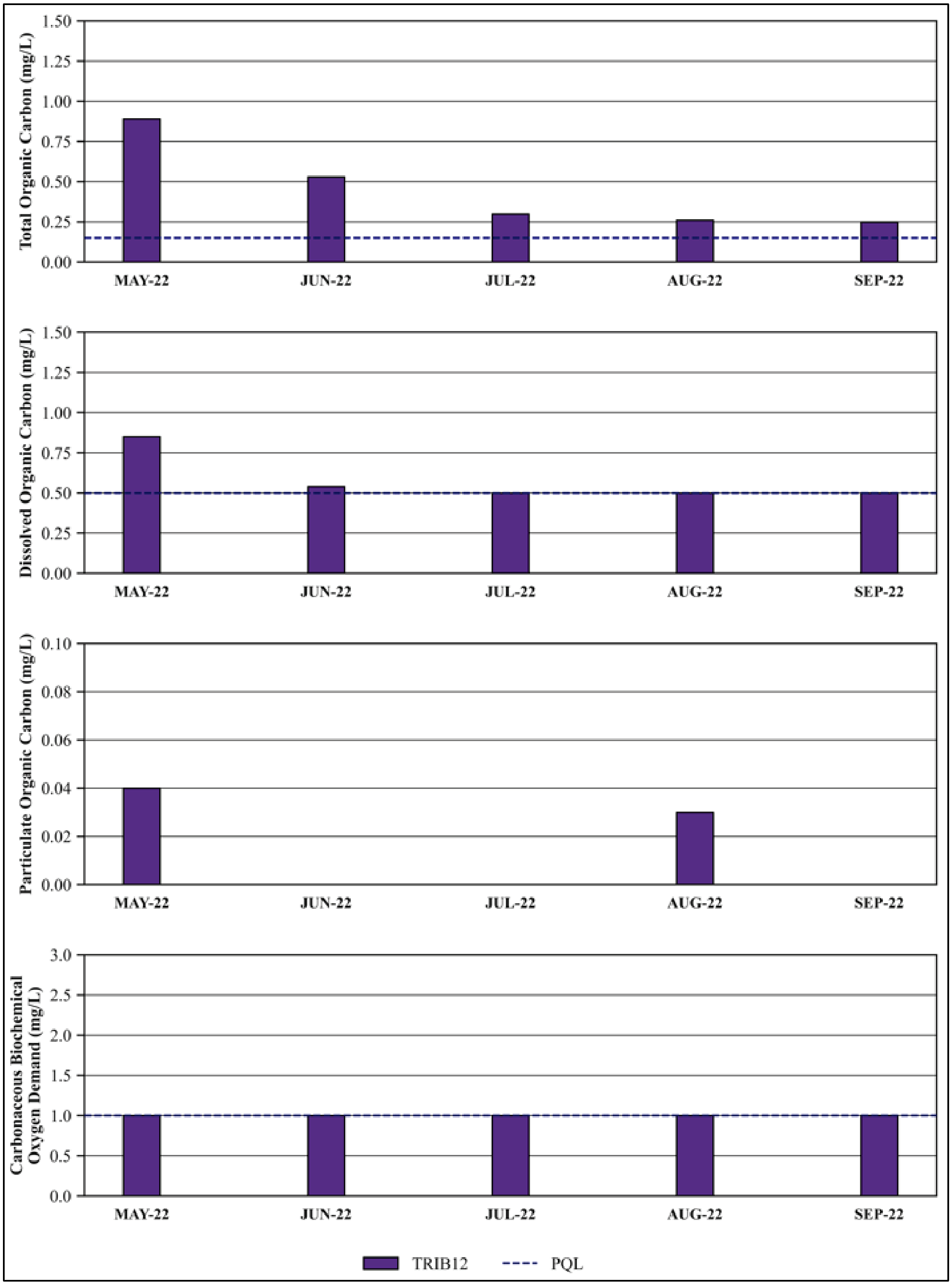



**Figure 5.1-37. Organic carbon and carbonaceous biochemical oxygen demand in Diablo Dam Forebay (DIABLO2), epilimnion, metalimnion, and hypolimnion (2022); PQL = practical quantitation limit.**




Note: Particulate organic carbon was estimated as the difference between total organic carbon and dissolved organic carbon. PQL = practical quantitation limit.

**Figure 5.1-38. Organic carbon and CBOD in Thunder Creek (TRIB12) (2022).**

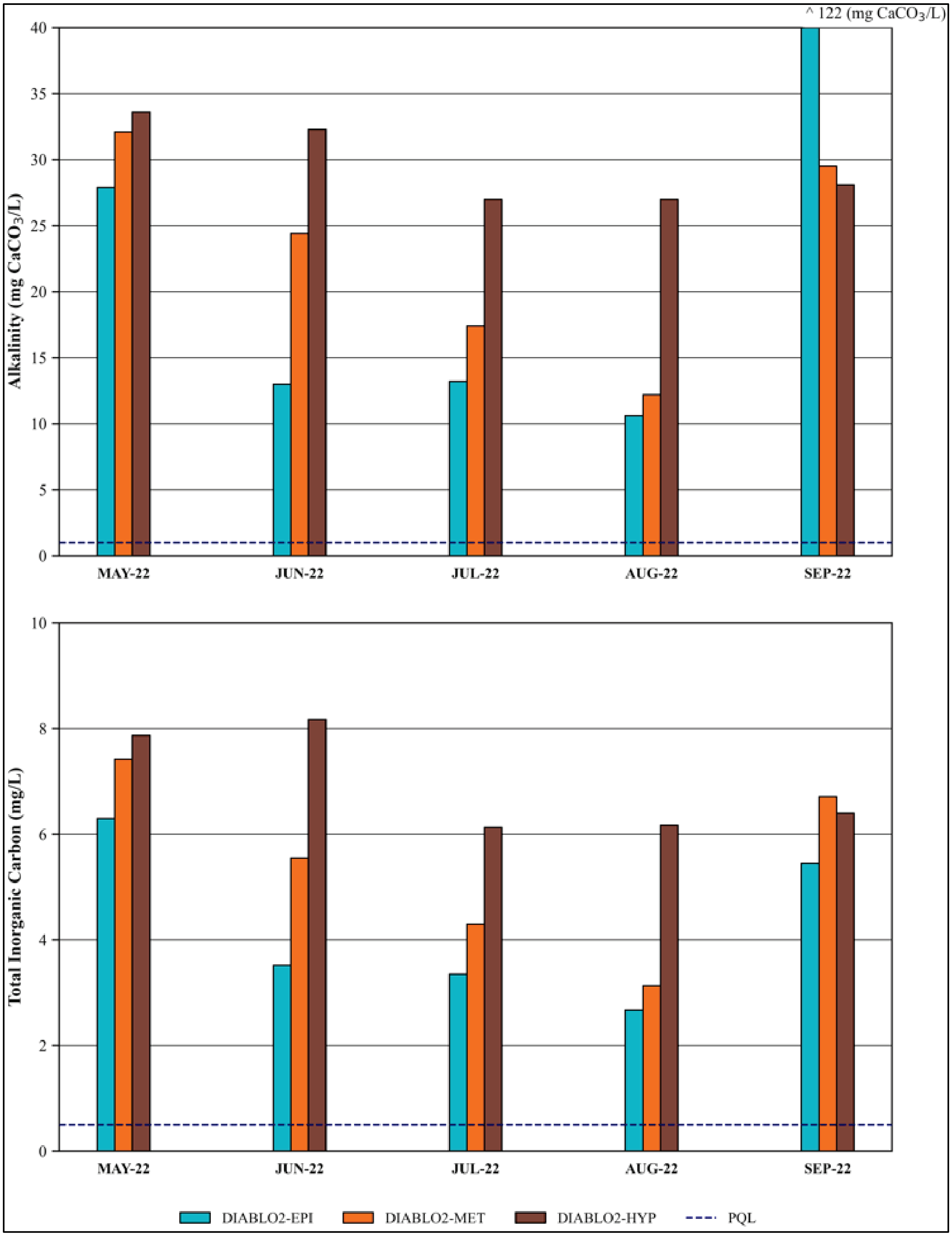



**Figure 5.1-39.** **TIC and alkalinity in Diablo Dam forebay (DIABLO2), epilimnion, metalimnion, and hypolimnion (2022); PQL = practical quantitation limit.**

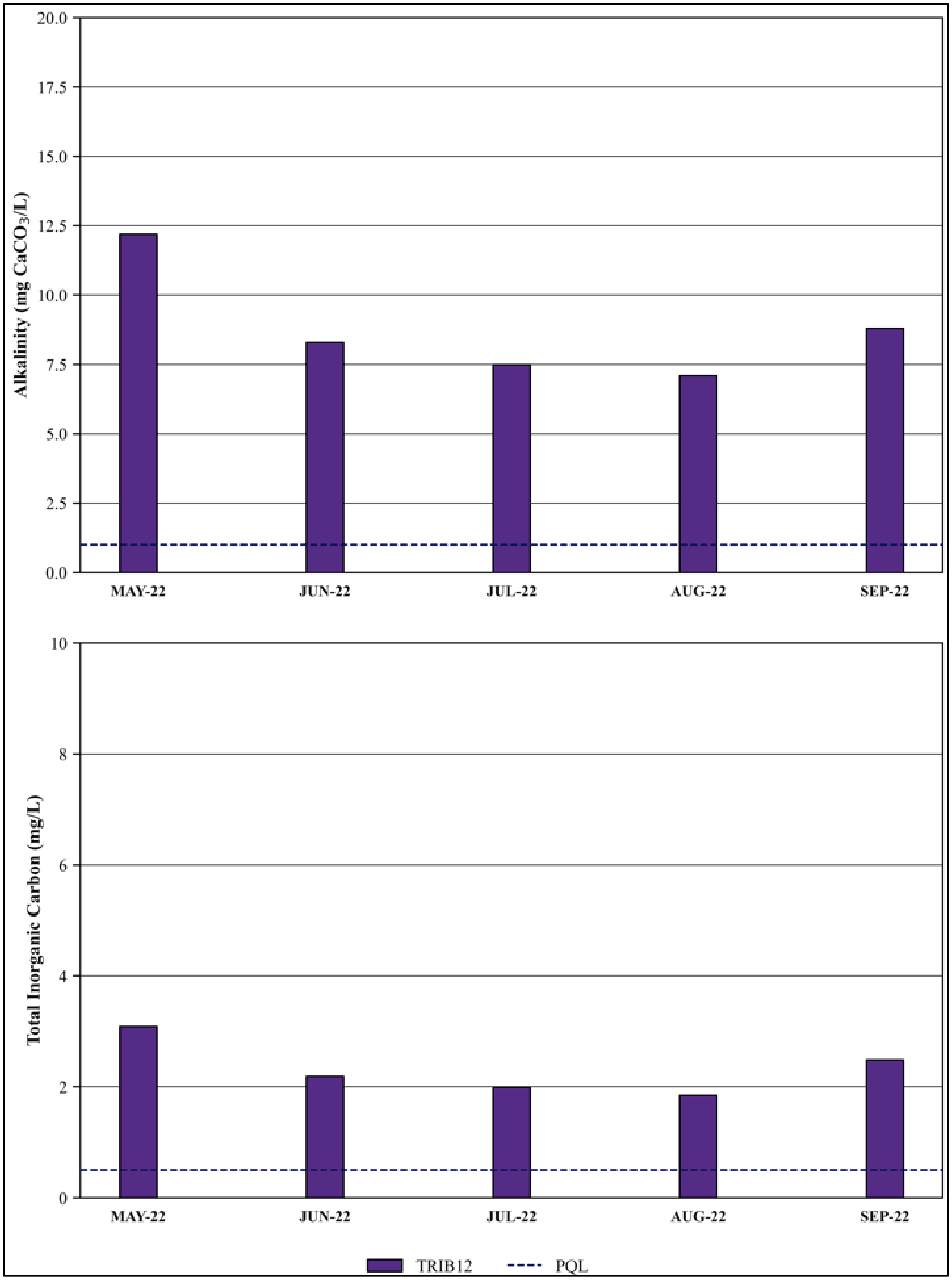



**Figure 5.1-40. TIC and alkalinity in Thunder Creek (TRIB12) (2022); PQL = practical quantitation limit.**

#### 5.1.2.7 Phytoplankton Taxonomy

Major phytoplankton taxa in Diablo Dam forebay and Thunder Creek are shown in Tables 5.1-13 and 5.1-14, respectively. As indicated in Section 5.1.1.6, June samples could not be enumerated because they had frozen. Phytoplankton data will be analyzed further when the complete set of phytoplankton taxonomic data is available.

**Table 5.1-13. Major phytoplankton taxa in Diablo Dam forebay (DIABLO2) (May-August 2022).**

| Sampling Date | Taxon Rank | Epilimnion | | Metalimnion | | Hypolimnion | |
|---|---|---|---|---|---|---|---|
| | | Taxon | Abundance (%) | Taxon | Abundance (%) | Taxon | Abundance (%) |
| May 24, 2022 | 1st | Unknown alga sp. | 48.0 | *Asterionella formosa* Hassall | 46.0 | *Dolichospermum* sp. | 25.2 |
| | 2nd | *Asterionella formosa* Hassall | 22.0 | *Cyclotella* spp. | 23.5 | *Cyclotella* spp. | 18.9 |
| | 3rd | *Cyclotella* spp. | 7.9 | *Cryptomonas* spp. | 10.7 | *Cryptomonas* spp. | 16.9 |
| | 4th | *Dinobryon* spp. | 7.6 | *Planktolyngbya* spp. | 9.8 | *Dinobryon* spp. | 15.9 |
| | 5th | *Achnanthidium* spp. Kützing | 4.3 | *Gomphonema* spp. | 1.8 | *Fragilaria* spp. | 6.5 |
| Jul 21, 2022 | 1st | *Dinobryon* spp. | 71.3 | *Dinobryon* spp. | 72.3 | *Dinobryon* spp. | 47.9 |
| | 2nd | Unknown Chrysophyte sp. | 18.7 | *Achnanthidium* spp. Kützing | 8.0 | *Fragilaria* spp. | 9.0 |
| | 3rd | *Fragilaria* spp. | 4.3 | *Hannaea arcus* (Ehrenberg) Patrick | 4.6 | *Achnanthidium* spp. Kützing | 9.0 |
| | 4th | *Cryptomonas* spp. | 3.0 | Unknown Chrysophyte sp. | 2.9 | *Cyclotella* spp. | 7.6 |
| | 5th | *Gomphonema* spp. | 0.7 | *Asterionella formosa* Hassall | 2.9 | *Cryptomonas* spp. | 5.6 |
| Aug 17, 2022 | 1st | *Dinobryon* spp. | 49.2 | *Aphanocapsa* spp. | 32.2 | *Dinobryon* spp. | 82.8 |
| | 2nd | *Aphanothece* spp. Nägeli | 14.6 | *Aphanothece* spp. Nägeli | 27.6 | *Cryptomonas* spp. | 4.5 |
| | 3rd | *Aphanocapsa* spp. | 12.5 | *Dinobryon* spp. | 15.2 | Unknown Chrysophyte sp. | 3.2 |
| | 4th | *Chrysococcus* sp. | 8.1 | *Chrysococcus* sp. | 7.4 | *Asterionella formosa* Hassall | 2.5 |
| | 5th | Unknown Chrysophyte sp. | 5.6 | Cryptomonas spp. | 4.9 | *Fragilaria* spp. | 2.2 |

Notes: Abundance is reported as a percentage of the overall cell counts for that Genera.
Only the top 5 major taxa are shown.

**Table 5.1-14. Major phytoplankton taxa in Thunder Creek (TRIB12) (May-August 2022).**

| Sampling Date | Taxon Rank | Taxon | Abundance (%) |
|---|---|---|---|
| May 24, 2022 | 1st | *Melosira* spp. | 29.8 |
| | 2nd | *Achnanthidium* spp. Kützing | 19.7 |
| | 3rd | *Hannaea arcus* (Ehrenberg) Patrick | 15.4 |
| | 4th | *Gomphonema* spp. | 10.8 |
| | 5th | *Tabellaria* spp. | 7.2 |
| Jul 21, 2022 | 1st | *Homoeothrix* spp. | 38.3 |
| | 2nd | *Hannaea arcus* (Ehrenberg) Patrick | 21.3 |
| | 3rd | *Achnanthidium* spp. Kützing | 10.6 |
| | 4th | Unknown Chrysophyte (cyst) spp. | 7.4 |
| | 5th | *Chantransia* sp. | 6.9 |
| Aug 17, 2022 | 1st | *Achnanthidium* spp. Kützing | 33.6 |
| | 2nd | *Hannaea arcus* (Ehrenberg) Patrick | 17.5 |
| | 3rd | *Gomphonema* spp. | 10.6 |
| | 4th | Unknown Chrysophyte sp. | 8.3 |
| | 5th | *Navicula* spp. | 6.0 |

Notes: Abundance is reported as a percentage of the overall cell counts for that Genera.
Only the top 5 major taxa are shown.

#### 5.1.2.8 Benthic and Drifting Macroinvertebrates

**Reservoir Benthic Sampling**

Results of PONAR sampling in Diablo Lake are shown in Figures 5.1-41 through 5.1-43. At the time of reporting, results were available only for samples collected in June, August, and early September 2022; data from samples collected in mid-September and October 2022 have not been received from the taxonomy laboratory. As discussed in Section 4.1.2.5, reported metrics include total abundance, taxa richness, percent EPT composition, and percent functional group composition.

In Diablo Lake, total BMI abundance (number of individuals per PONAR sample) was relatively consistent between June and August, with most site-level variation observed in September (Figure 5.1-41). Across sampling events, cumulative abundance was highest at Thunder Arm North (811 individuals), followed by Main Basin (168 individuals), Skagit Arm (67 individuals), and Thunder Arm South (49 individuals). While relatively consistent, observed abundances were slightly lower in August than in June for all sites, ranging from 22-45 individuals at Skagit Arm, 14-15 individuals at Thunder Arm North, 9-12 individuals at Thunder Arm South, and 70-86 individuals at Main Basin. In September, total abundance decreased at Main Basin (12 individuals) and increased at Thunder Arm North and South (782 and 29 individuals, respectively); no September sample was collected at Skagit Arm. Although Thunder Arm North exhibited the highest cumulative abundance, this result is derived almost entirely from the early September sampling event, during which large quantities of midges (*Sergentia sp.*) and oligochaete worms (*Naididae*) were collected. Otherwise, total abundances ranged from 9-86 individuals per sampling event and predominantly comprised midges (e.g., *Stictochironomus sp., Tanytarsus*), freshwater clams (e.g., *Pisidium sp., Sphaeriidae*), and oligochaete worms (e.g., *Naididae*).

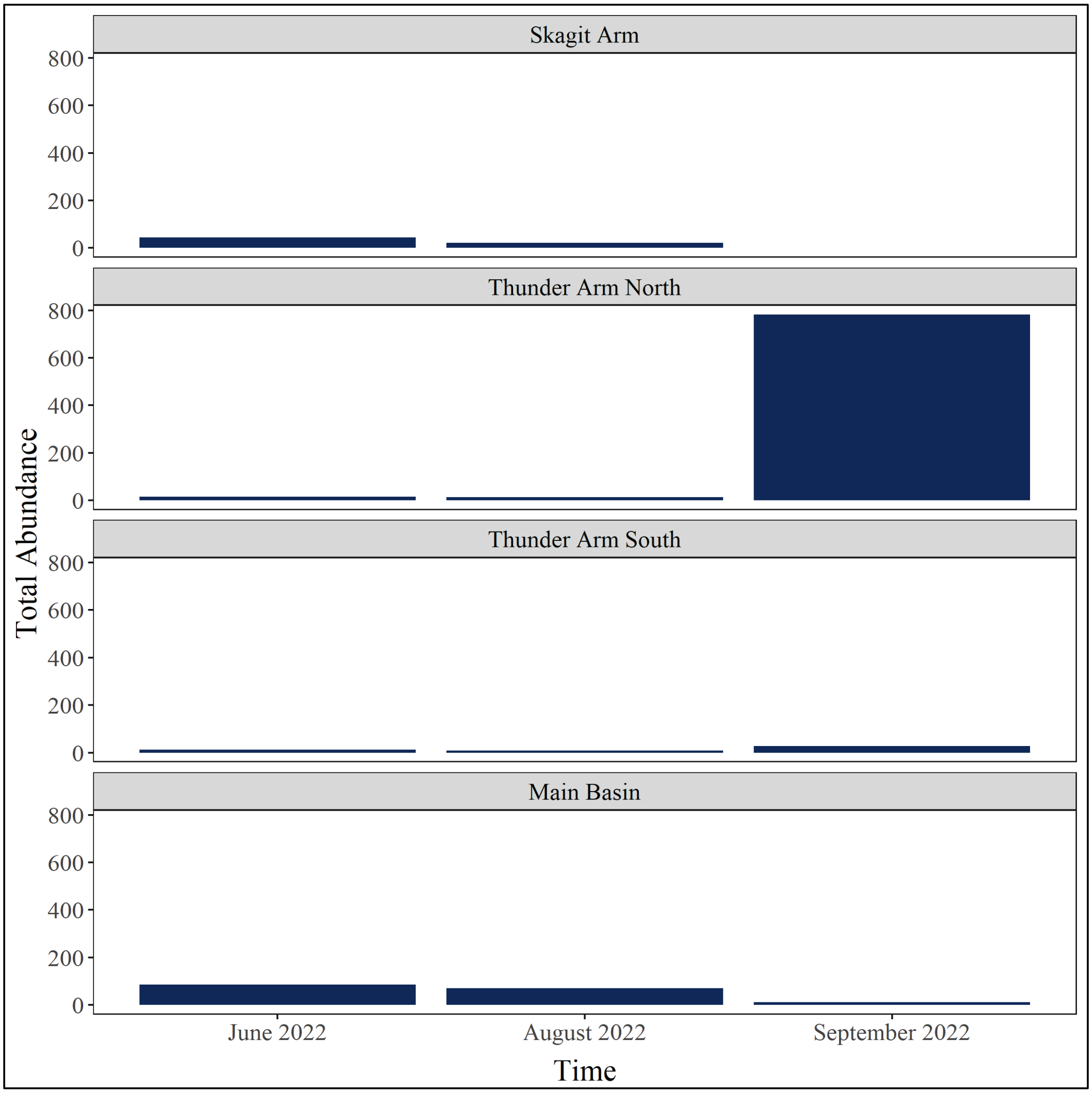



**Figure 5.1-41. BMI total abundance of PONAR samples (number of individuals per PONAR sample) collected at Skagit Arm, Thunder Arm North, Thunder Arm South, and Main Basin (June, August, and September 2022).**

Similar to total abundance, taxa richness tended to be relatively consistent in June and August but exhibited site-level differences in September (Figure 5.1-42). At Skagit Arm and Main Basin, taxa richness ranged from 7-15 taxa in June and August, followed by an apparent decline in September; of note, no sample was collected at Skagit Arm in September (see Section 4.1.4.2). The two Thunder Arm sites generally exhibited lower but similarly consistent taxa richness in June and August, ranging from 3-9 taxa, followed by an increase in September. Taxa richness was notably higher for the aforementioned early September sampling event at Thunder Arm North, during which abundance was high and 27 taxa were collected.

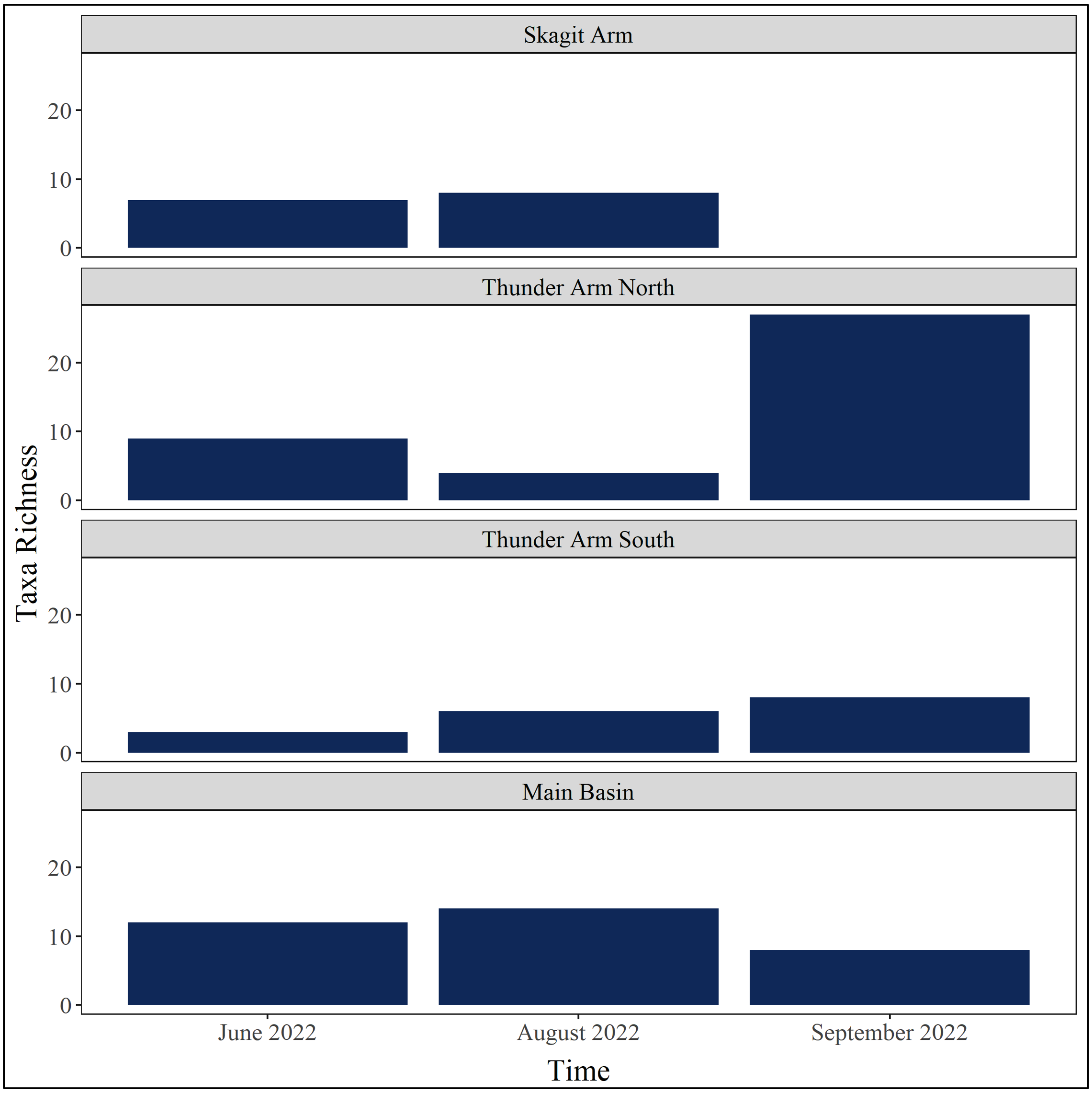
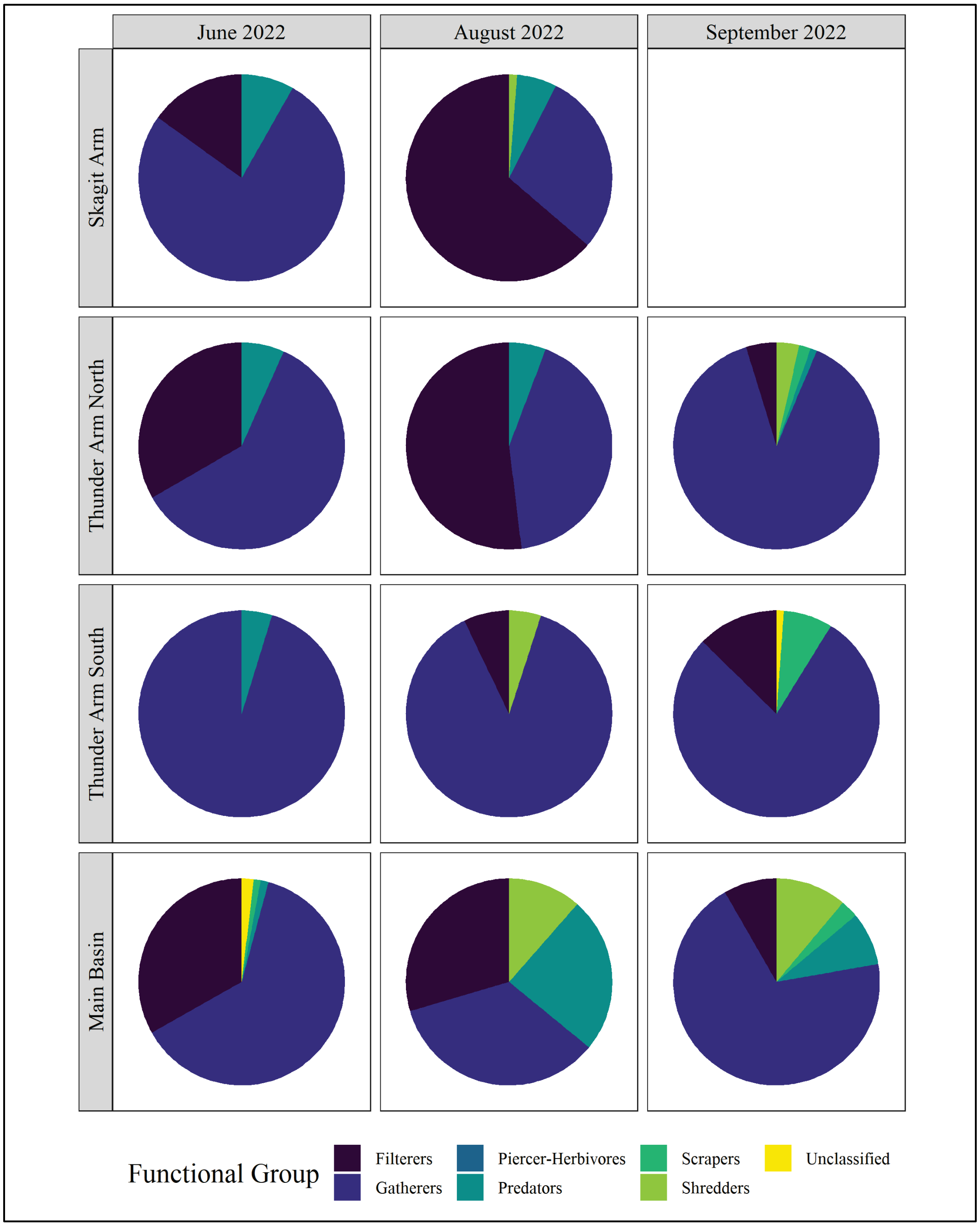



**Figure 5.1-42. BMI taxa richness of PONAR samples collected at Skagit Arm, Thunder Arm North, Thunder Arm South, and Main Basin (June, August, and September 2022).**

Percent EPT composition was low across sites and seasons. Although EPT taxa were collected at all sites, they never constituted more than 4 percent of the total sample. Single caddisfly individuals (*Psychoglypha sp.* And *Mystacides sp.*) were collected in June and August at Main Basin (less than 0.7 and less than 0.8 percent of sample, respectively), in August at Skagit Arm (1 percent), and in early September in Thunder Arm South (4 percent). A single mayfly individual (*Ephemerellidae*) was collected in early September at Thunder Arm North (0.1 percent).

Diablo Lake PONAR samples indicate a BMI community dominated by gatherers, though filterers also made up large proportions of some samples (Figure 5.1-43). Gatherers were dominant across sites in June (60-95 percent of samples) and September (69-89 percent); although also abundant in August, proportions of gatherers were more variable across sites (29-88 percent). Filterers were abundant at most sites in June (15-33 percent, though absent from Thunder Arm South) and August

(7-64 percent), with declining proportions in September (4-12 percent). Predators, shredders, and scrapers were generally increasingly abundant as the sampling season progressed but made up small proportions of each sample (less than 12 percent, but 24 percent of the Main Basin sample in August).




Note: For a given sample, functional group composition represents the mean of individual functional group percentages across constituent replicate samples. No sample was collected at Skagit Arm in September (resulting in a blank plot).

**Figure 5.1-43. Functional group composition of PONAR samples collected at Skagit Arm, Thunder Arm North, Thunder Arm South, and Main Basin (June, August, and September 2022).**

### Kicknet Sampling

Results of benthic kicknet sampling in Thunder Creek are shown in Figures 5.1-44 through 5.1-47. At the time of reporting, results were available only for samples collected in early and late August 2022; data from samples collected in September 2022 had not been received from the taxonomy laboratory. As discussed in Section 4.1.2.5, reported metrics include total abundance, taxa richness, percent EPT composition, and functional group composition.

Total BMI abundance was higher in late August (483 individuals) than early August (292 individuals; Figure 5.1-44). Taxa richness also increased as the month progressed, with 34 taxa observed in early August and 40 taxa observed in late August (Figure 5.1-45). EPT comprised a large proportion of each kicknet sample, totaling 93 percent in early August and 87 percent in late August (Figure 5.1-46). Across sampling events, samples were dominated by mayfly taxa (*Baetis bicaudatus*, *Epeorus sp.,* and *Rhithrogena sp.*) and stonefly taxa (*Chloroperlidae*; Figure 5.1-47). The relative abundance and diversity of EPT taxa present may indicate good water quality and the presence of high-quality forage for stream fishes (King County 2015).

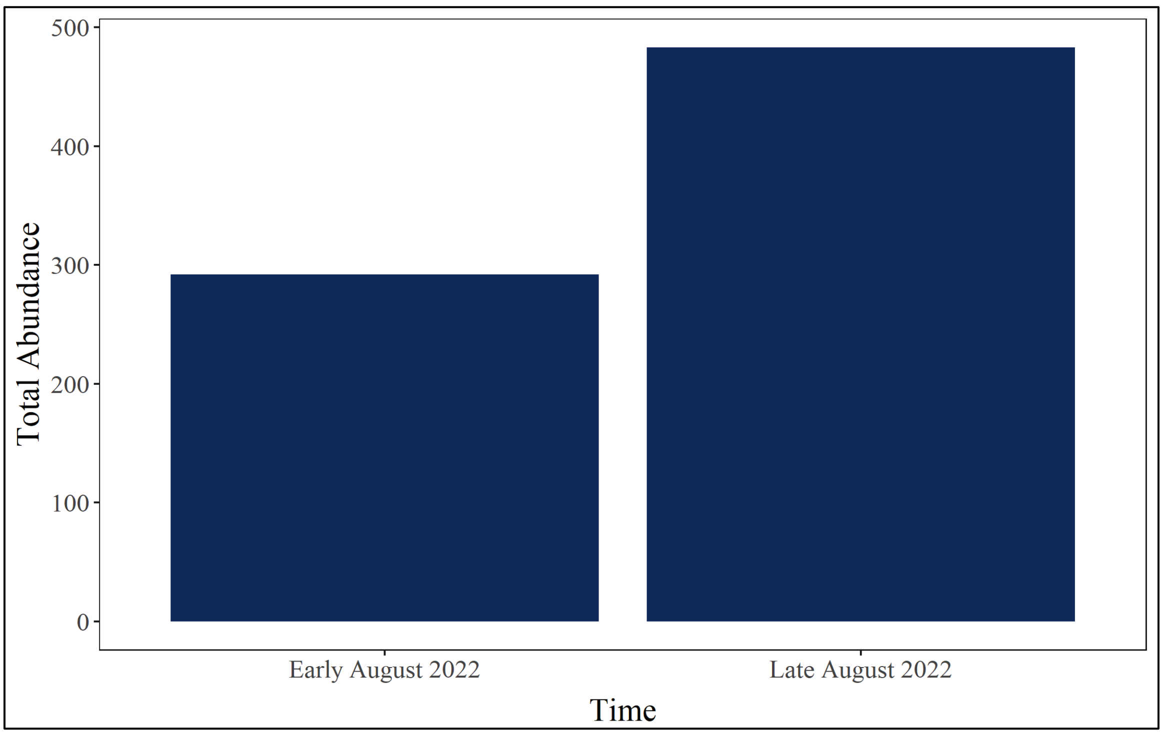



**Figure 5.1-44. BMI total abundance of kicknet samples collected at Thunder Creek (early and late August 2022).**

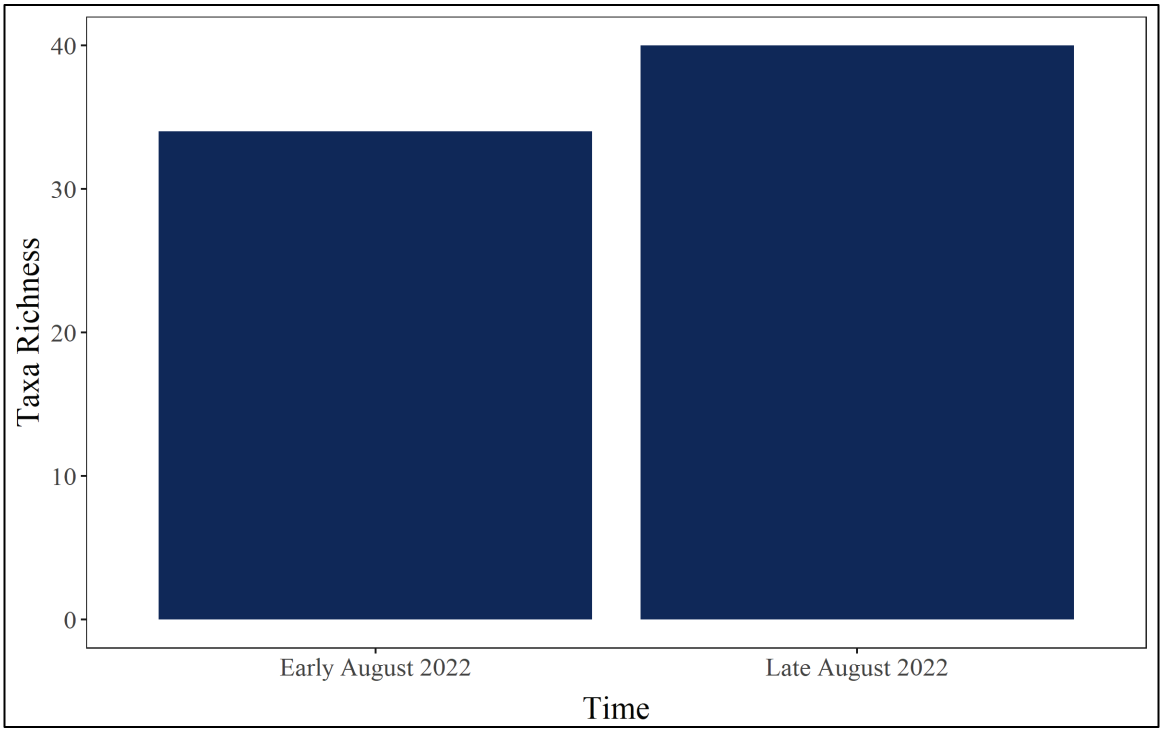



**Figure 5.1-45. BMI taxa richness of kicknet samples collected at Thunder Creek (early and late August 2022).**

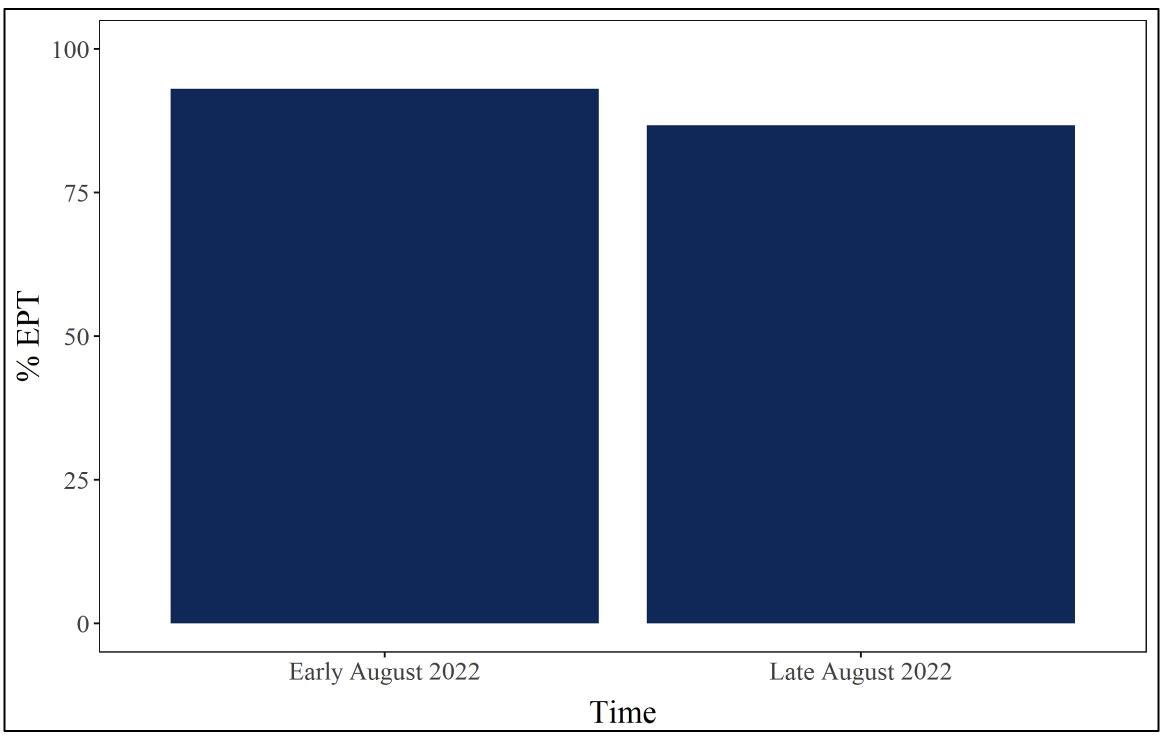



**Figure 5.1-46. Percent EPT composition of kicknet samples collected at Thunder Creek (early and late August 2022).**

Thunder Creek kicknet samples indicate a diverse BMI community, which exhibited similar functional group composition for both sampling events (Figure 5.1-47). Scrapers were dominant in both early and late August samples, comprising 44 and 47 percent of samples, respectively. Gatherers also constituted a large proportion of each sample (29 and 37 percent, respectively). Predators were abundant as well (21 and 12 percent, respectively), while a small proportion of each sample comprised shredders (less than 2.5 percent) and filterers (less than 0.5 percent).

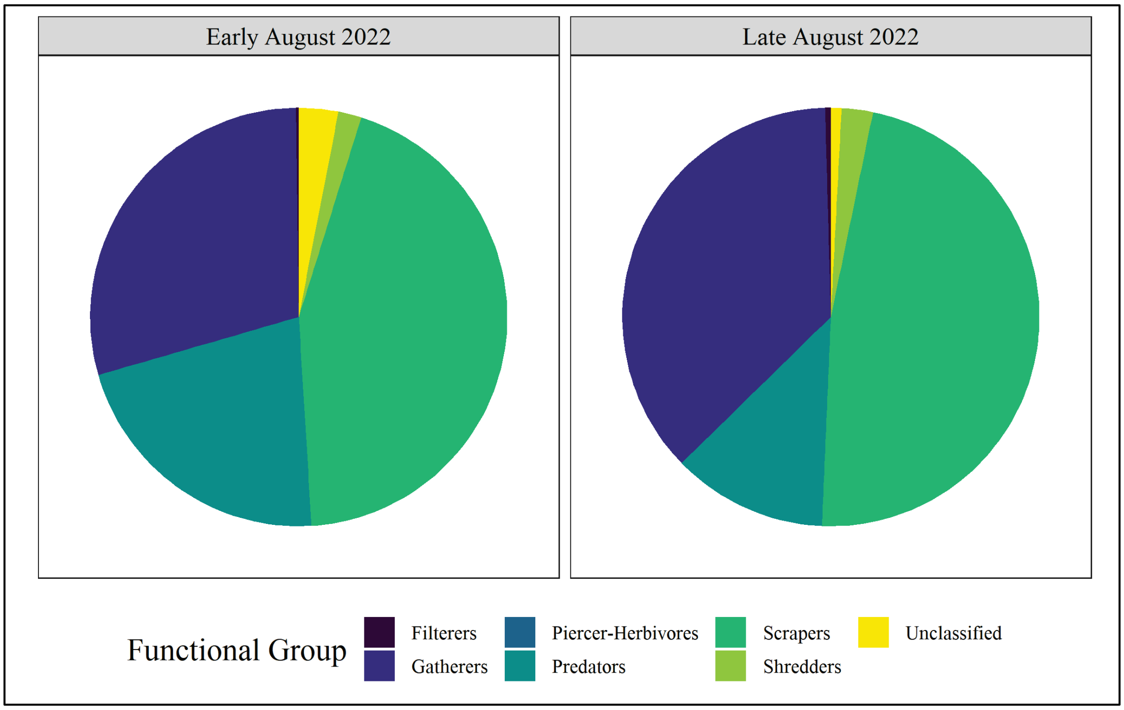



**Figure 5.1-47. Functional group composition of kicknet samples collected at Thunder Creek (early and late August 2022).**

### Drift Sampling

Results of drift sampling in Thunder Creek are shown in Figures 5.1-48 through 5.1-52. At the time of reporting, results were available only for samples collected in early and late August 2022; data from samples collected in September 2022 had not been received from the taxonomy laboratory. As discussed in Section 4.1.2.5, reported metrics include total abundance, taxa richness, percent EPT composition, biomass density, and functional group composition.

Total abundance of drifting invertebrates was higher in late August (252 individuals) than early August (95 individuals; Figure 5.1-48). Taxa richness also increased as the month progressed, with 36 taxa observed in early August and 50 taxa observed in late August (Figure 5.1-49). EPT comprised a moderate proportion of each drift sample (31 and 26 percent in early and late August, respectively), a further indication of good water quality and the presence of high-quality forage for stream fishes in Thunder Creek (Figure 5.1-50). All samples were dominated by a single chironomid taxon (*Orthocladius [Euorthocladius]*). Various mayfly taxa (*Baetis bicaudatus, Baetis tricaudatus*) and chironomid taxa (*Chironomidae*) were also abundant. Drift biomass density was low during both sampling periods but approximately twice as high in late August ($3.1 \times 10^{-5}$ g/m$^3$) as in early August ($1.5 \times 10^{-5}$ g/m$^3$; Figure 5.1-51).

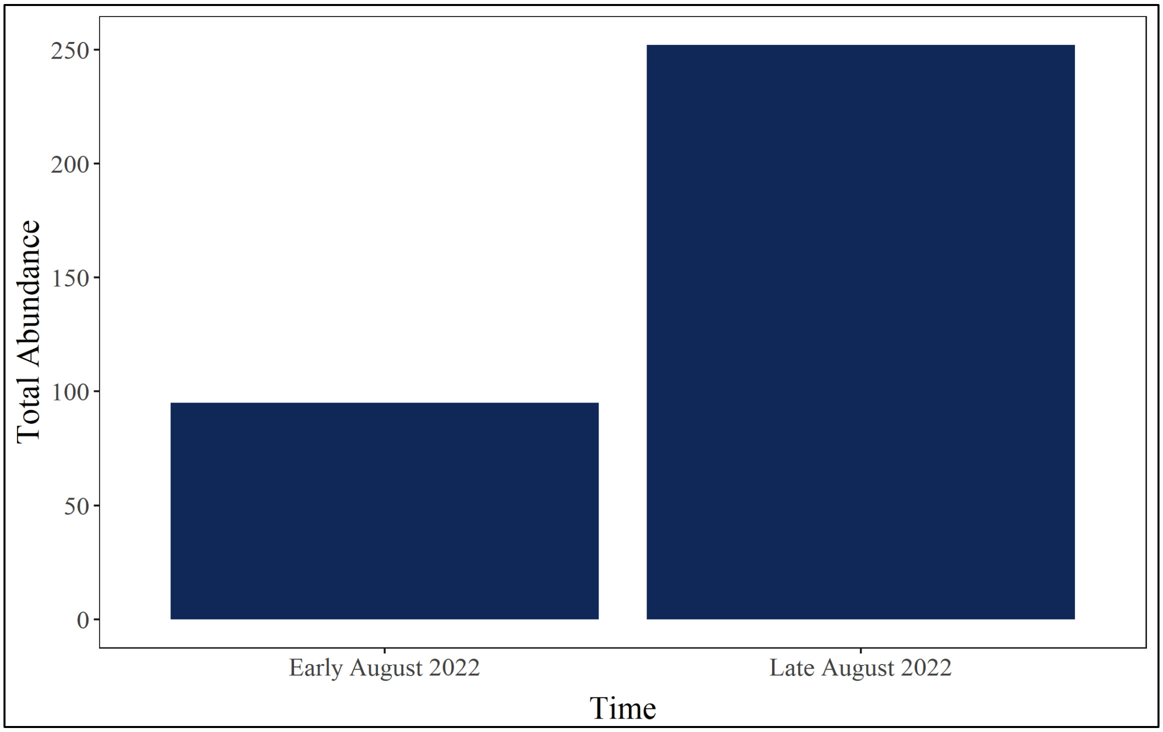



**Figure 5.1-48.** **Total abundance of invertebrates in drift samples collected at Thunder Creek (early and late August 2022).**

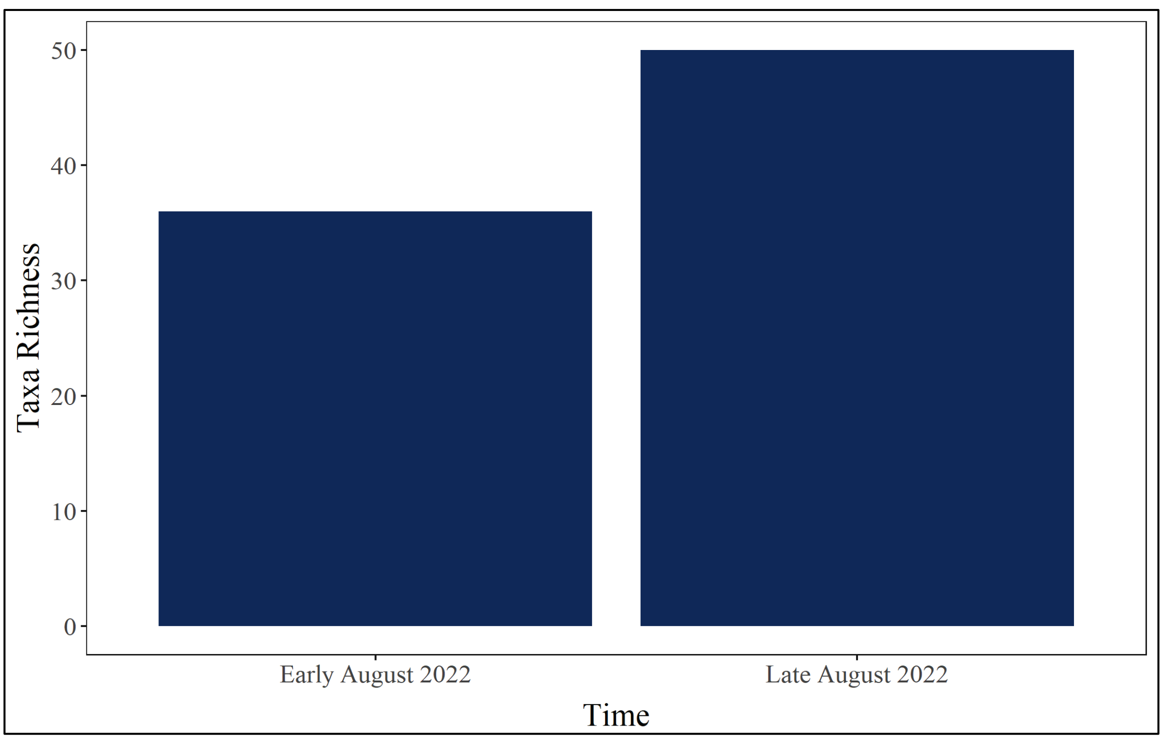



**Figure 5.1-49.** **Taxa richness of invertebrates in drift samples collected at Thunder Creek (early and late August 2022).**

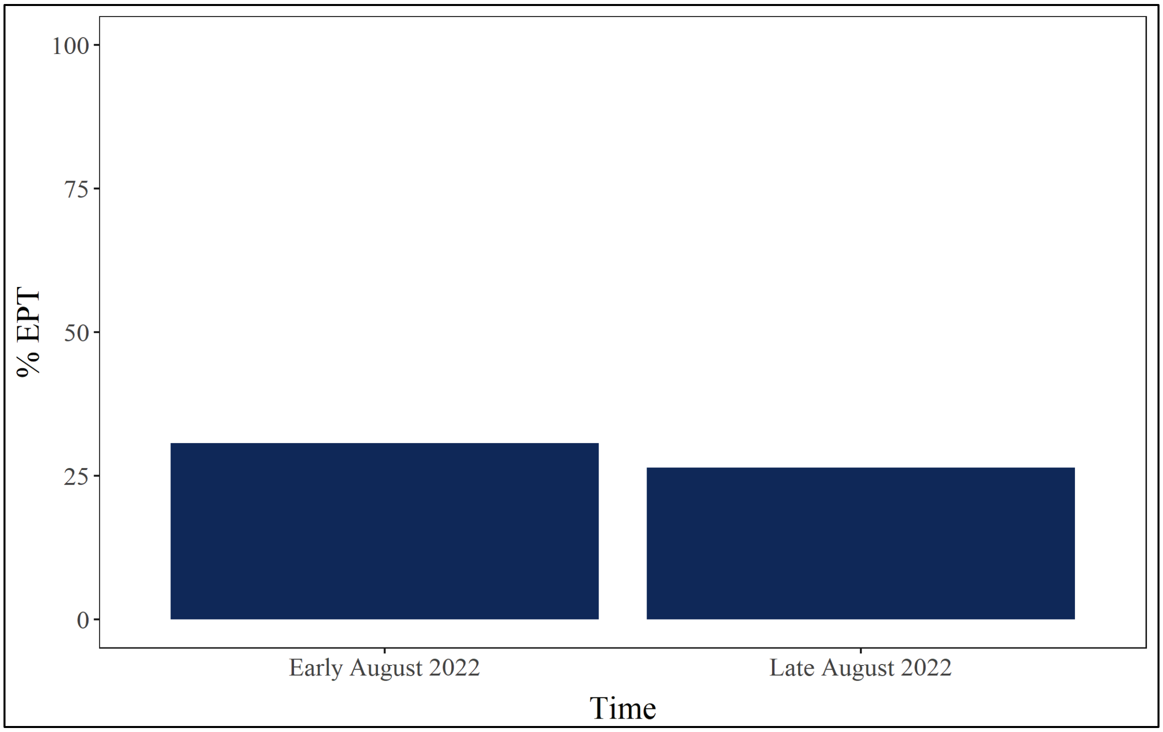



**Figure 5.1-50. Percent EPT composition of drift samples collected at Thunder Creek (early and late August 2022).**

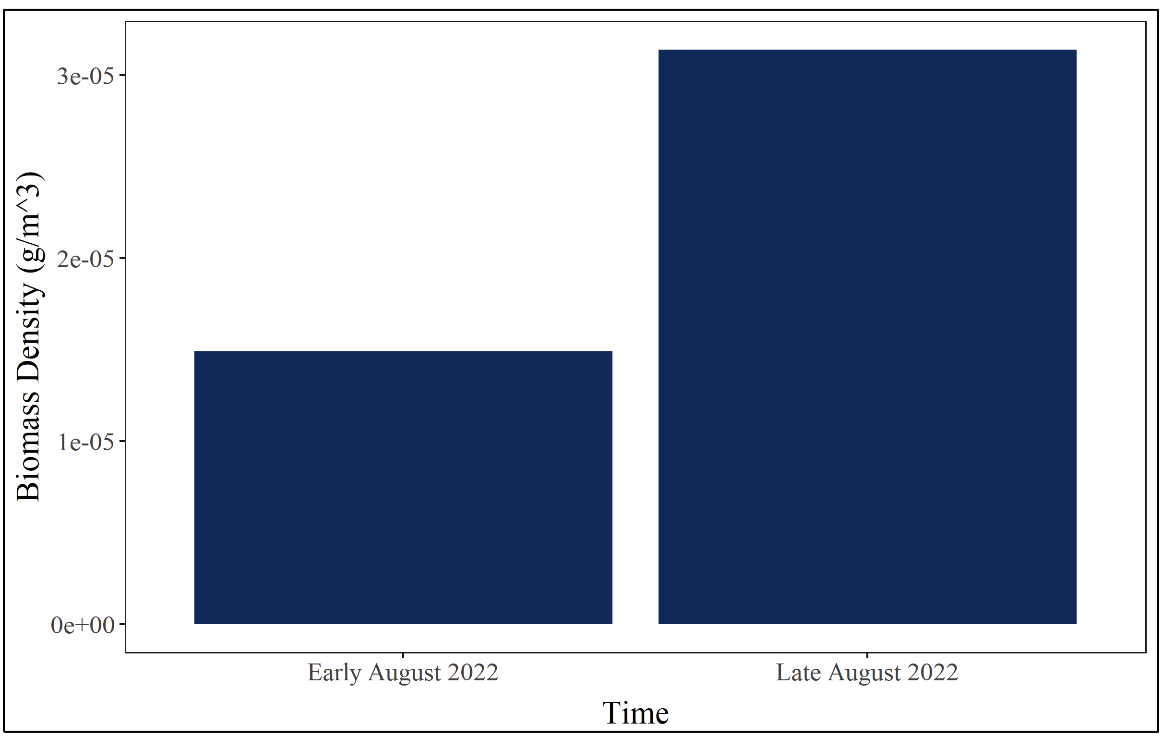



**Figure 5.1-51. Invertebrate biomass density of drift samples collected at Thunder Creek (early and late August 2022).**

Thunder Creek drift samples indicate a community dominated by gatherers, with similar functional group composition observed across sampling events (Figure 5.1-52). Gatherers constituted a majority of the early August sample (61 percent) and the late August sample (70 percent). Predators also constituted a notable proportion of the early August sample (11 percent) but a smaller proportion of the late August sample (6 percent). Filterers, shredders, and scrapers constituted a comparatively small proportion of each sample (less than or equal to 7 percent). A large proportion of each sample comprised unclassified, predominantly terrestrial taxa (13 and 11 percent, respectively).

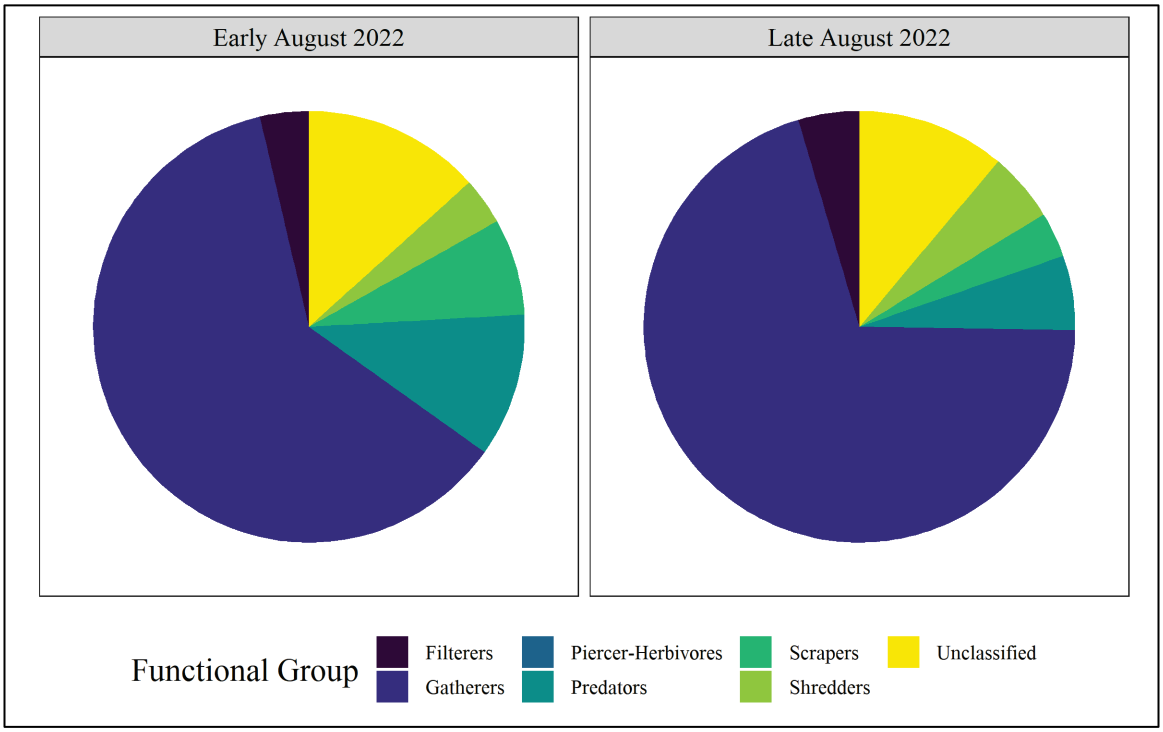



**Figure 5.1-52. Functional group composition of drift samples collected at Thunder Creek (early and late August 2022).**

### 5.1.2.9 QA/QC

As noted in Section 4.2, a field duplicate sample was collected during each field visit. Diablo and Gorge lakes were typically visited during the same sampling event, thus a duplicate was collected at one of the two sites on each reservoir and at one of two depths at each site, immediately following routine sample collection. Duplicates were measured for turbidity and TSS, and their RSD was calculated to assess sample variability in the field. Results for duplicate samples are shown below for Diablo Lake (Table 5.1-15). 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 5.1-15. Results of field duplicate measurements of turbidity and total suspended solids at Diablo Lake (June 2021-August 2022).**

| Date | Site ID | Turbidity (NTU) | | | TSS (mg/L) | | |
|---|---|---|---|---|---|---|---|
| | | R | D | RSD | R | D | RSD |
| Jun-21 | DIABLO1 5-m | 2.5 | 2.8 | 8.0 | 3 | 2 | 28.3 |
| Jul-21 | DIABLO2 1-m | 2.9 | 2.8 | 2.5 | ND | 3 | N/A |
| Sep-21 | DIABLO2 5-m | 1.2 | 1.2 | 0.0 | ND | ND | N/A |
| Dec-21 | DIABLO1 1-m | 14 | 14 | 0.0 | 3 | ND | N/A |
| Jan-22 | DIABL01 5-m | 7.9 | 8 | 0.9 | ND | ND | N/A |
| Feb-22 | DIABLO2 1-m | 5.2 | 5.2 | 0.0 | ND | ND | N/A |
| May-22 | DIABLO1 1-m | 0.71 | 0.75 | 3.9 | ND | ND | N/A |
| Jun-22 | DIABLO2 1-m | 1.2 | 1.7 | 24.4 | ND | ND | N/A |
| Aug-22 | DIABLO2 5-m | 2.2 | 2.3 | 3.1 | ND | ND | N/A |

Notes: R = routine; D = Duplicate; RSD = Relative Standard Deviation, calculated as (S*100)/mean.

For turbidity, RSD values exceeded 5 percent in June 2021 (8.0 percent) and June 2022 (24.4 percent). For TSS, RSD values of 28.3 percent were measured in June in Diablo Lake, with no TSS detected in the other two duplicate samples collected. As discussed in Section 5.1.3.8 regarding violation of the QAPP RSD criteria in Gorge Lake, high RSDs reflect low values and small differences between duplicate pairs, thus the impact on data quality and overall confidence in terms of accurately characterizing turbidity and TSS in Diablo Lake are deemed negligible.

Results of blank sample analyses were non-detectable for all TSS samples. Detectable turbidity was reported for nine of the 13 blank samples measured from June 2021 through September 2022. Turbidity for blank samples averaged 0.2 NTUs and ranged from 0.1 to 0.6 NTUs.

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 96 percent data completeness in 2021. All other parameters at both DIABLO1 and DIABLO2 were 100 percent complete in 2021 and 2022. All visits were conducted per the schedule outlined in the RSP, except November 2021, when there was no access to the Project area due to flooding downstream.

For the May 2022 expanded water quality sampling at the Diablo Dam forebay and Thunder Creek, chlorophyll *a* results were flagged as estimated because of a holding time violation that resulted from a delay in shipping the chlorophyll *a* samples by Edge Laboratory to its subcontractor ALS that performed the analysis. All chlorophyll *a* samples for subsequent events were field filtered and shipped with ice and sent to EcoAnalysts, Inc. (where the taxonomic analysis was also conducted) to comply with the very short hold time requirements needed for water samples.

### 5.1.3 Gorge Lake

Beginning in June 2021, *in situ* vertical profile measurements of temperature, DO, and pH have been made at roughly monthly intervals at the upstream end of Gorge Lake at Reflector Bar across from the Diablo Powerhouse (GORGE1) and near the Gorge Dam intake along the southern side of the forebay log boom (GORGE2). From June 2021 through September 2022, vertical profile measurements have been conducted in Gorge Lake at elevations of approximately 877-881 ft (267-268-m) NAVD 88 (871-875 ft [265-267-m] CoSD; USGS Gorge Reservoir near Newhalem gage [12177700]). Per the PAD, average elevation in Gorge Lake over a 28-year period, 1991-2018 ranges from approximately 874 to 878 ft (266 to 268-m) NAVD 88 (868 to 872 ft [264 to 266-m] CoSD) (City Light 2020).

#### 5.1.3.1 Temperature

Data from 2014-2019 show that Gorge Lake was colder than Diablo Lake, with similar minimum temperatures but with summer maximum temperatures only slightly above 12°C (Figure 5.1-53). The Gorge Lake water column was nearly isothermal to a depth of 80 ft (24-m) during most of the year, with a peak difference of approximately 1°C between surface water and water at 80 ft (24-m) during summer. The summer maxima observed in Gorge Lake from 2014-2019 are higher than the monthly average temperatures measured at the Skagit River inflow at Swing Bridge from 2002-2019 (see Figure 5.1-1).

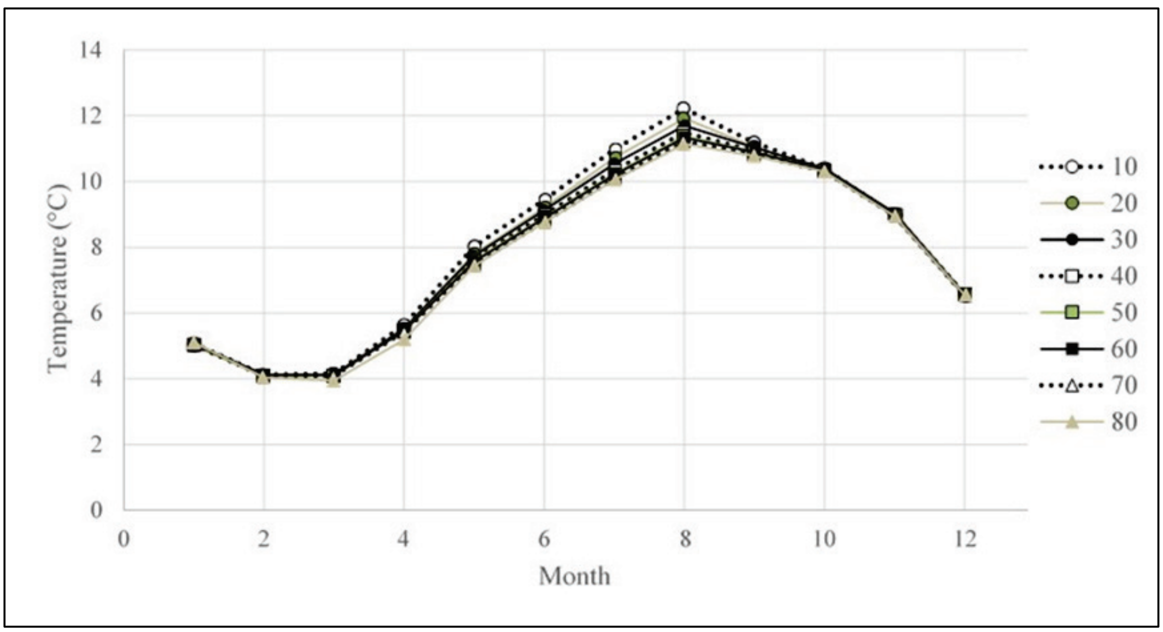



**Figure 5.1-53. Monthly average water temperature at 8 depths at the log boom monitoring location in Gorge Lake (2014-2019). Source: City Light data collected outside of relicensing.**

Stetattle Creek was the only Gorge Lake tributary monitored prior to relicensing studies (2005-2019), 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 5.1-54).

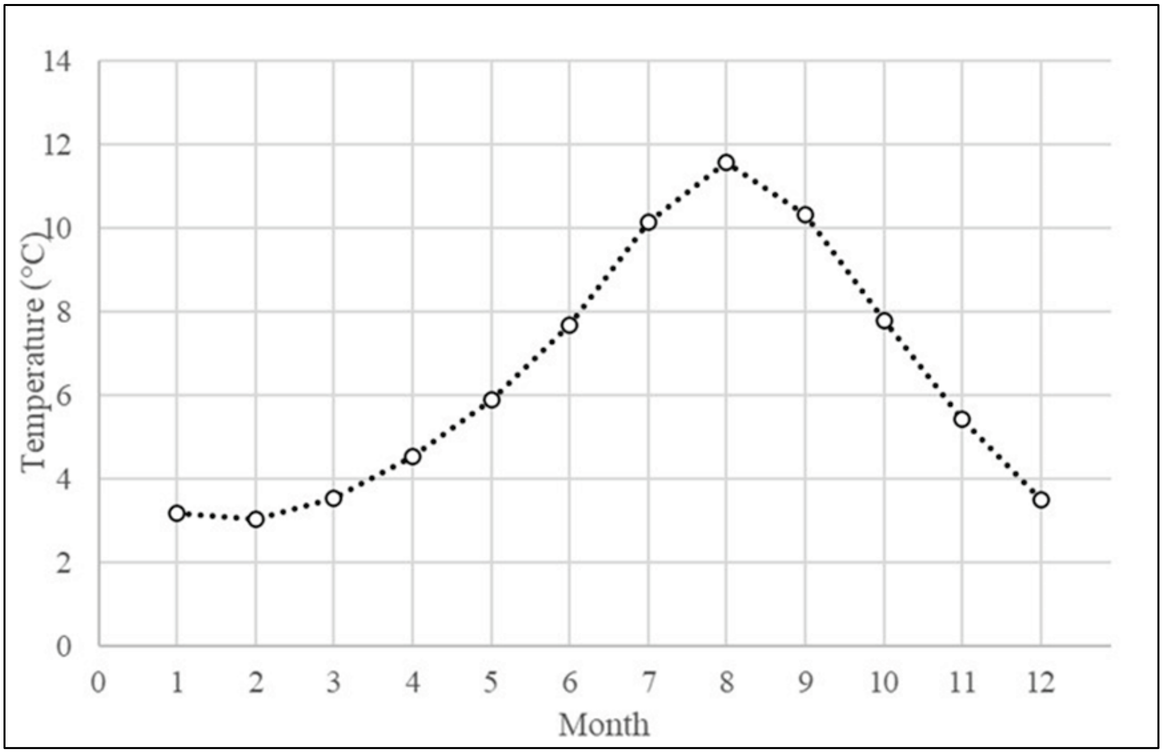



**Figure 5.1-54. Monthly average of continuous temperature data measured in Stetattle Creek (2005-2019). Source: City Light data collected outside of relicensing.**

Surface temperatures measured in 2021 were highest in July at Reflector Bar, across from Diablo Powerhouse (GORGE1,13.6°C) and in August at the Gorge Dam forebay (GORGE2, 12.8°C). Weak stratification is seen in June at GORGE1 and in June and July, 2021 at GORGE2 (Figure 5.1-55), although there was also a thermal gradient evident at GORGE2 in August. Gorge Lake was weakly stratified from June through August in 2022 (Figure 5.1-56).

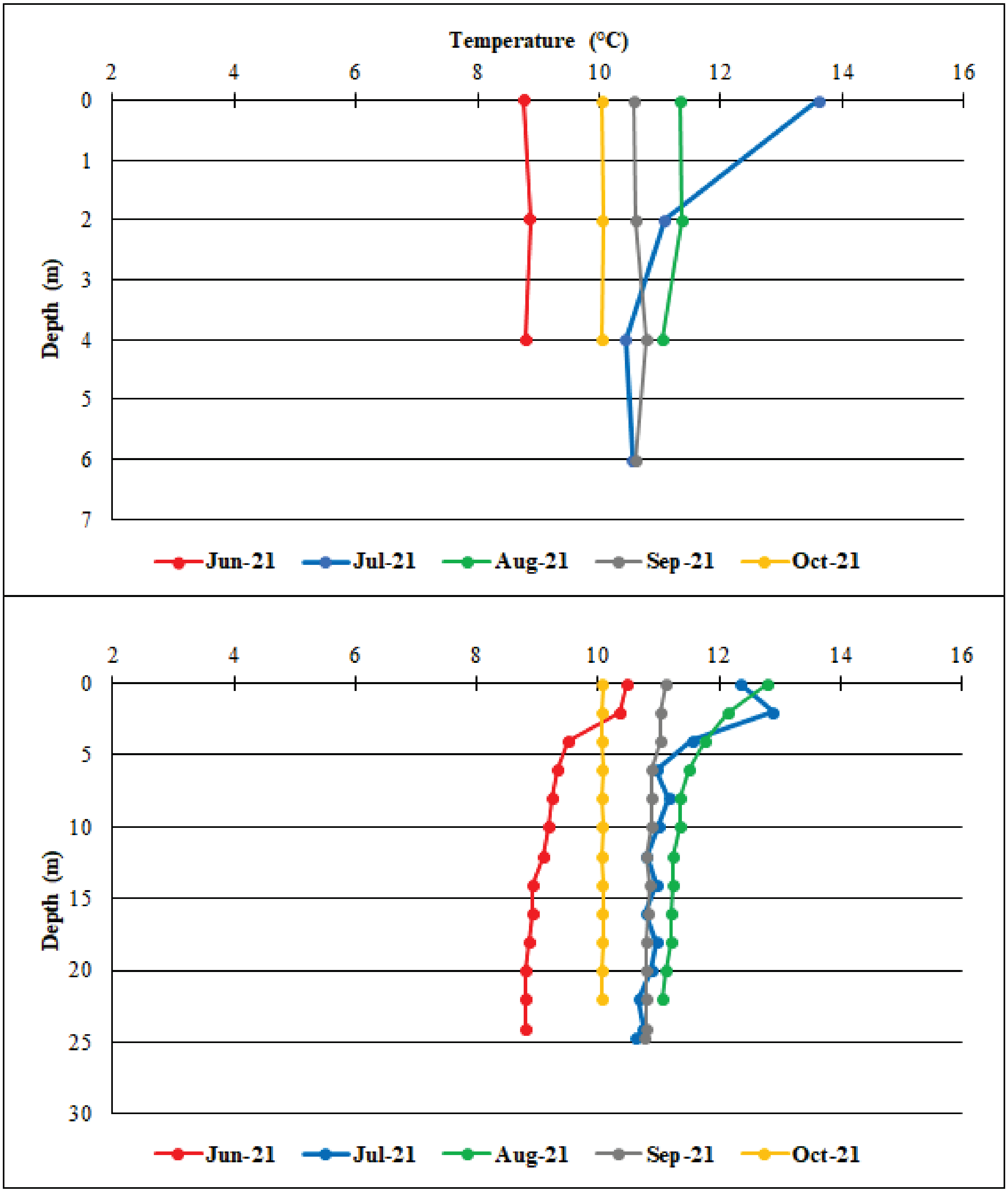



**Figure 5.1-55. Temperature profile at the upstream end of Gorge Lake at Reflector Bar (GORGE1, top) and in the forebay (GORGE2, bottom) (June-October 2021).**

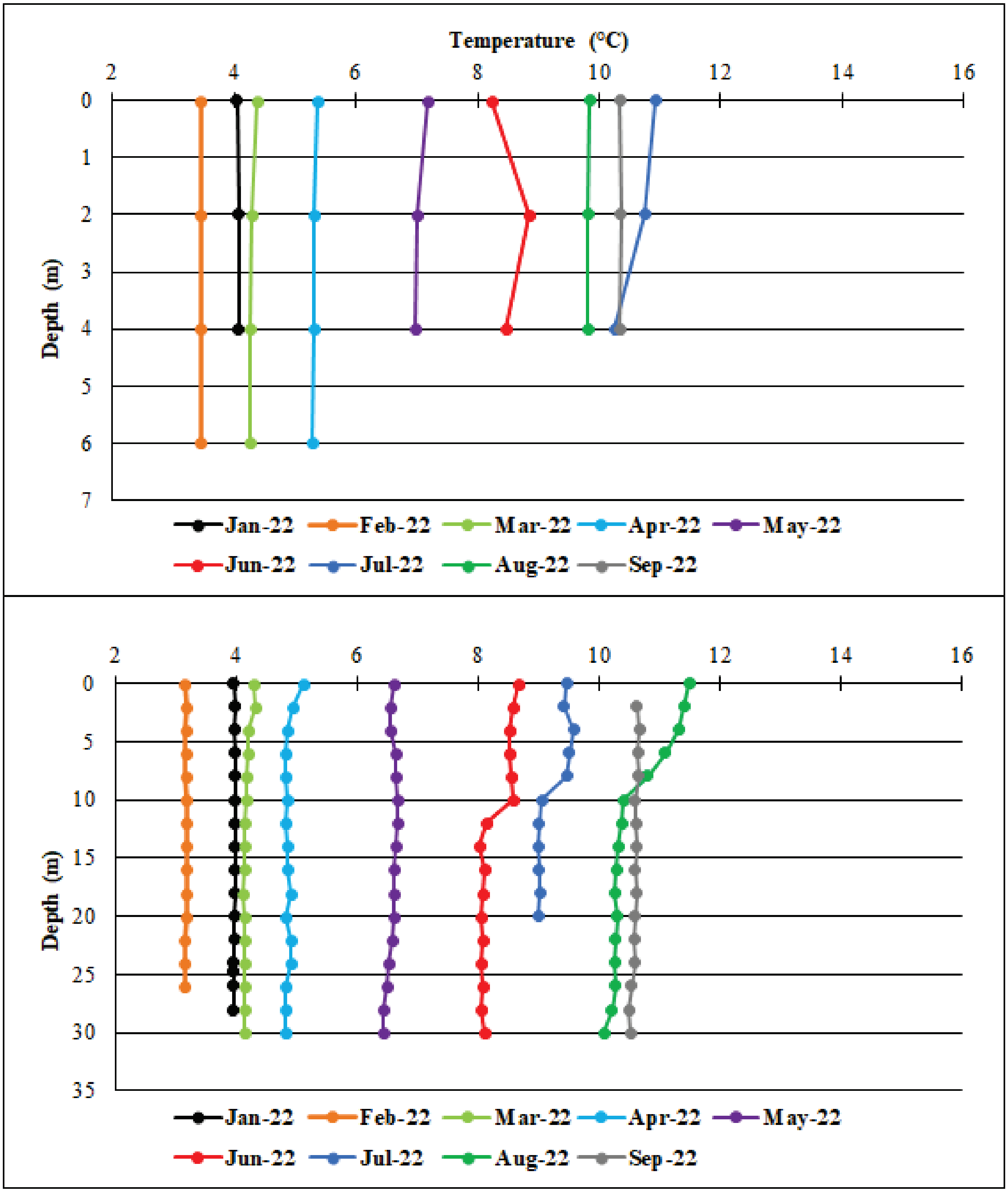



**Figure 5.1-56. Temperature profile at the upstream end of Gorge Lake at Reflector Bar (GORGE1, top) and in the forebay (GORGE2, bottom) (January-September 2022).**

#### 5.1.3.2 Dissolved Oxygen

Gorge Lake exhibits well-oxygenated conditions throughout much of the water column. DO profiles at GORGE1 and GORGE2 are shown in Figures 5.1-57 and 5.1-58. Values in 2021 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 882 ft (269-m) NAVD 88 (875 ft [267-m] 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 (Figure 5.1-57). Remaining profile measurements were generally 10 to 11 mg/L throughout the water column.

DO concentrations were highest (14-15 mg/L) during the winter months of 2022 (January, February, March), corresponding to months with lowest temperatures (Figure 5.1-58). Minimum DO during 2022 was in September, consistently around 11 mg/L throughout the water column.

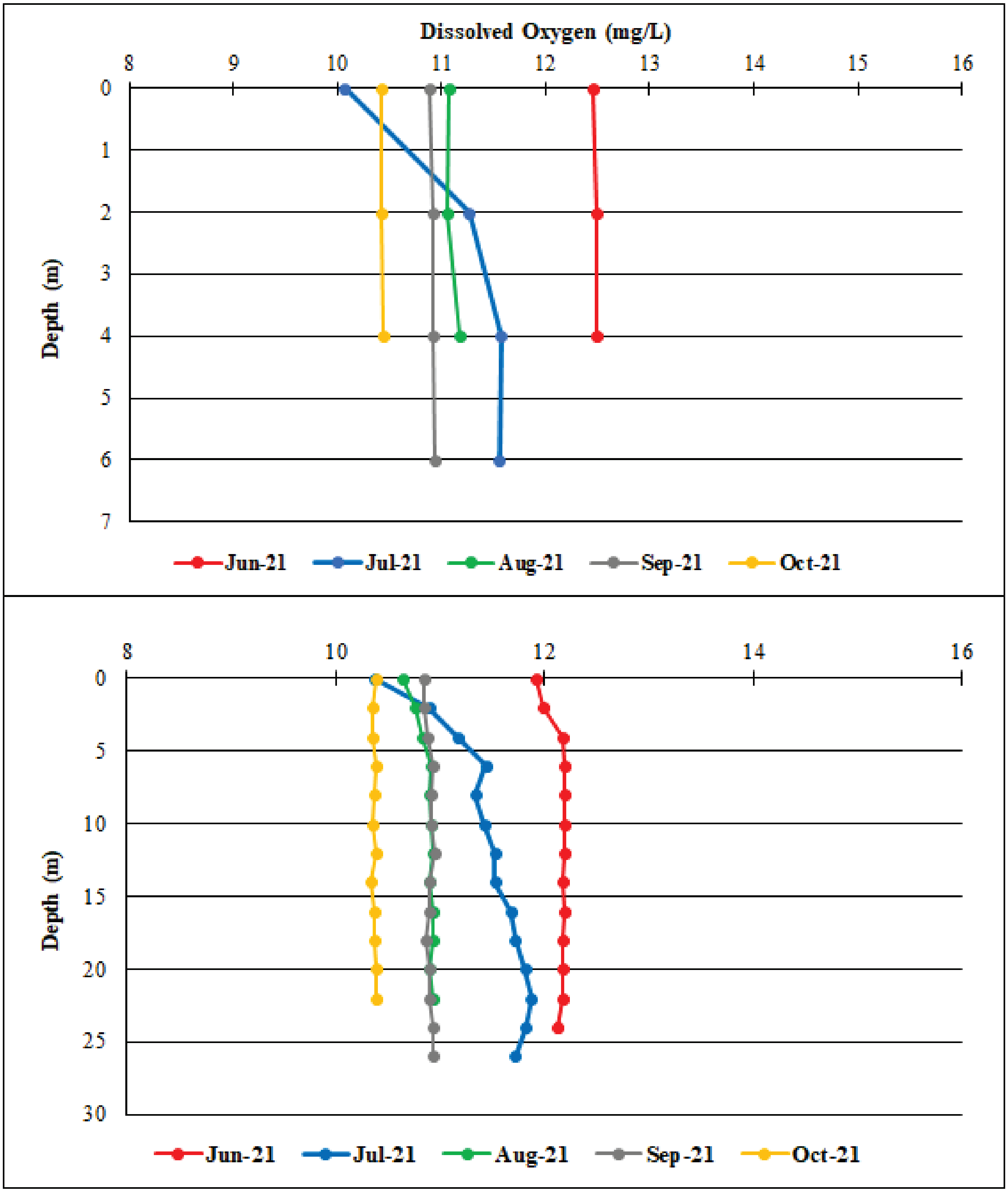



**Figure 5.1-57. DO profiles at the upstream end of Gorge Lake at Reflector Bar (GORGE1, top) and in the forebay (GORGE2, bottom) (June-October 2021).**

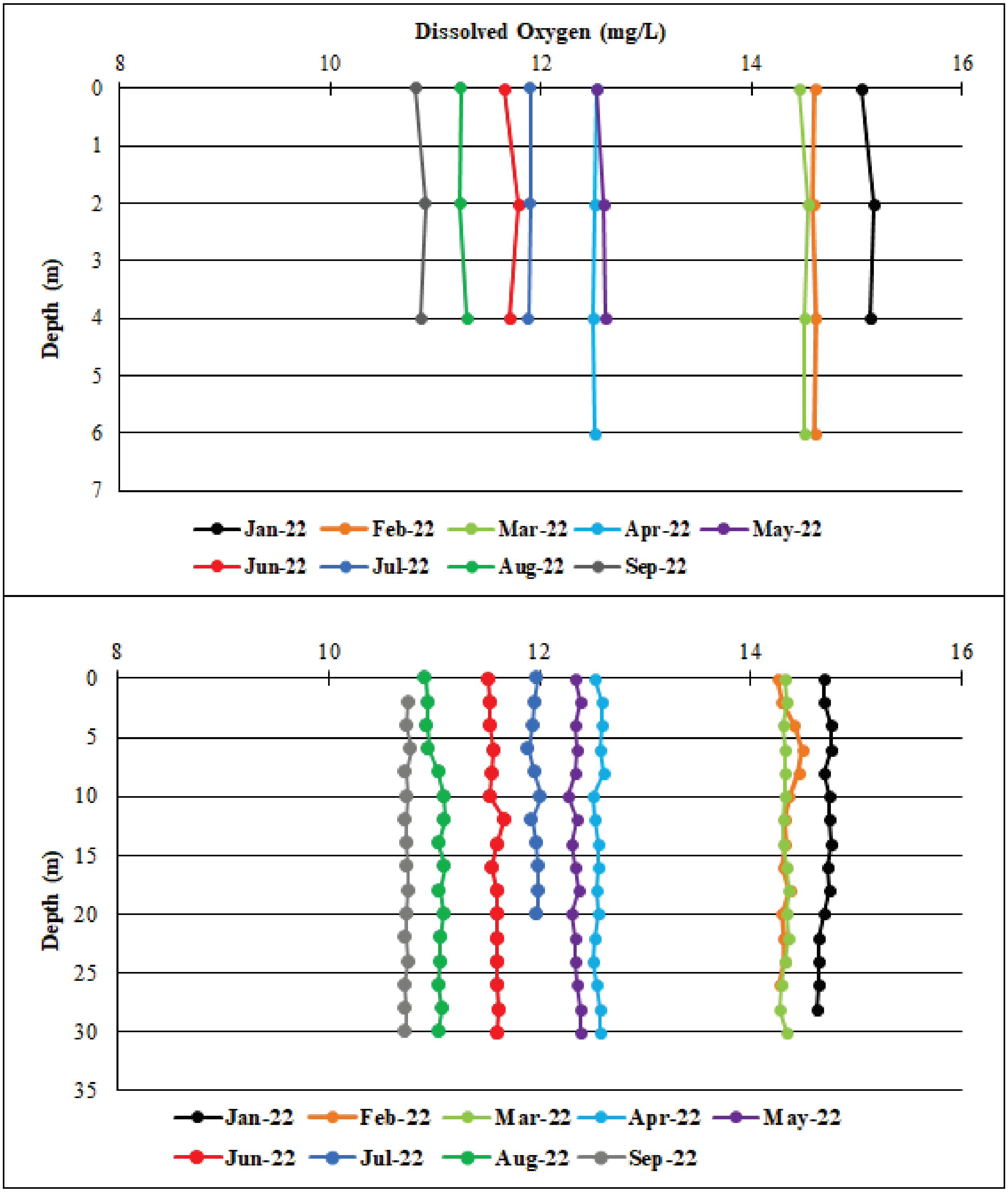
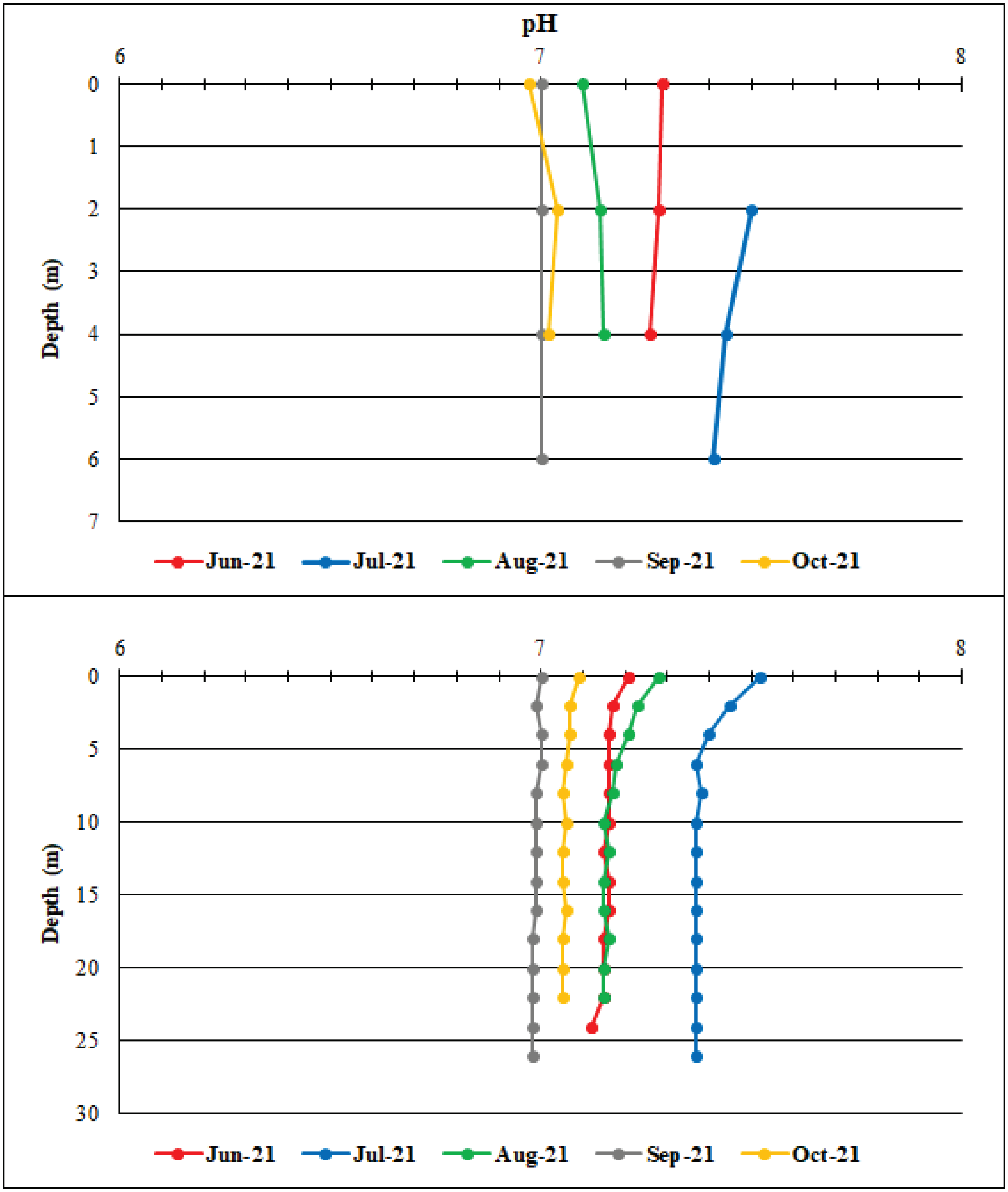



**Figure 5.1-58.** **DO profiles at the upstream end of Gorge Lake at Reflector Bar (GORGE1, top) and in the forebay (GORGE2, bottom) (January-September 2022).**

#### 5.1.3.3 pH

Profiles of pH at the two Gorge Lake sites are shown in Figures 5.1-59 and 5.1-60. Profiles for pH were very similar from surface to bottom for both 2021 and 2022. In 2021, pH values along profiles at GORGE1 and GORGE2 were between 7.0 and 7.5. In 2022, pH values measured along vertical profiles at both sampling locations were comparatively low (between pH values of 6.5 and 7.2, with one outlier at 7.5), with little variation from surface to bottom.

As seen in Diablo Lake (Section 5.1.2.3) vertical profiles of pH in Gorge Lake in 2021 were higher than in 2022, possibly a result of greater primary production. DO displayed an opposite pattern (generally lower in 2021 than 2022), likely a result of warmer water temperatures in 2021.




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

**Figure 5.1-59. pH profiles at the upstream end of Gorge Lake at Reflector Bar (GORGE1, top) and in the forebay (GORGE2, bottom) (June-October 2021).**

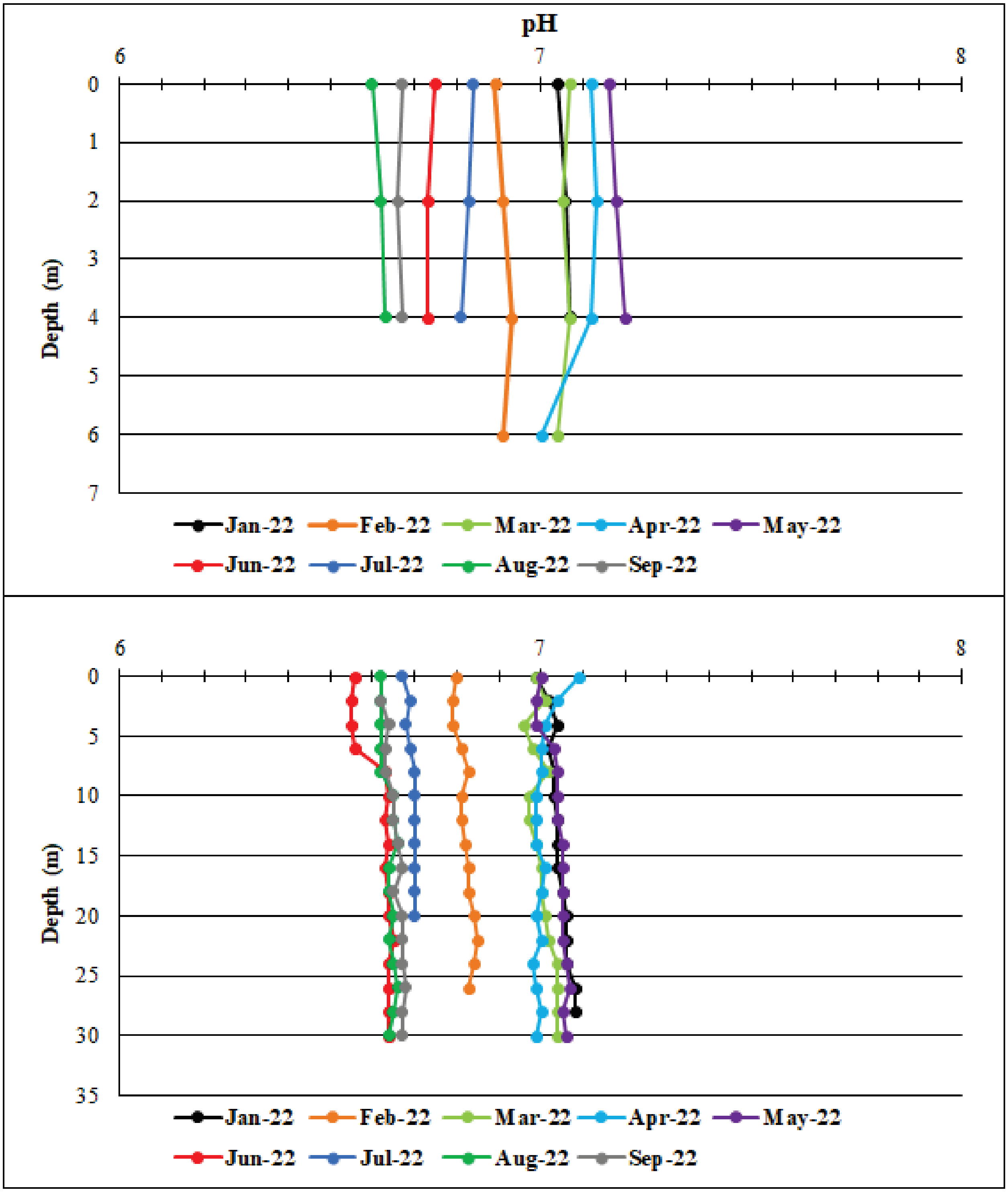



**Figure 5.1-60.** **pH profiles at the upstream end of Gorge Lake at Reflector Bar (GORGE1, top) and in the forebay (GORGE2, bottom) (January-September 2022).**

#### 5.1.3.4 Turbidity and Total Suspended Solids

Measurements of turbidity and TSS at both GORGE1 and GORGE2 are shown in Table 5.1-16. Average turbidity (June 2021 through September 2022) was just under 3 NTUs for each site on Gorge Lake. Turbidity was less than 5 NTUs from June through September during both years, and, similar to Diablo, increased during the winter months to near 10 NTUs in January.

**Table 5.1-16. Turbidity and total suspended solids at Reflector Bar (GORGE1) and the Gorge Dam forebay (GORGE2) at 1- and 5-m depths (June 2021-September 2022).**

| Date | Reservoir Elevation (ft) (NAVD 88 and CoSD) | GORGE1 | | | | GORGE2 | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 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-21 | 879 (872) | 3.1 | 2.3 | 2 | 3 | 1.7 | 2.3 | 1 | 3 |
| Jul-21 | 878 (871) | 1.8 | 2 | 2 | ND | 1.9 | 1.9 | 2 | 2 |
| Aug-21 | 877 (870) | 2.6 | 2.8 | 3 | 3 | 2.7 | 3.1 | 2 | 2 |
| Sep-21 | 877 (870) | 0.88 | 1.4 | ND | ND | 0.87 | 1.3 | ND | ND |
| Oct-21 | 872 (865) | 6 | 5.8 | 3 | ND | 6.4 | 6.8 | 3 | 3 |
| Nov-21 | *No Access* | | | | | | | | |
| Dec-21 | *No Access* | | | | | | | | |
| Jan-22 | 879 (872) | 9.6 | 9.8 | 2 | 2 | 9.4 | 9.4 | 4 | ND |
| Feb-22 | 877 (870) | 5.3 | 5.2 | ND | 2 | 5.1 | 5.4 | 2 | ND |
| Mar-22 | 880 (873) | 2.6 | 2.6 | ND | ND | 2.5 | 2.5 | ND | ND |
| Apr-22 | 875 (868) | 0.82 | 0.79 | ND | ND | 0.88 | 0.84 | ND | ND |
| May-22 | 881 (874) | 1.1 | 0.79 | ND | ND | 0.95 | 0.8 | ND | ND |
| Jun-22 | 879 (872) | 1.6 | 1.3 | ND | ND | 1.2 | 1.1 | ND | ND |
| Jul-22 | 879 (872) | 2.6 | 2.2 | 2.5 | 3.5 | 2.1 | 2.8 | 2 | 2 |
| Aug-22 | 878 (871) | 1.5 | 1.4 | ND | ND | 1.4 | 1.3 | ND | ND |
| Sep-22 | 879 (872) | 0.65 | 0.84 | ND | 2 | 0.72 | 0.65 | ND | ND |

Notes: All elevations in the table are NAVD 88 with CoSD value in parentheses.
GORGE1 = Upper end of Gorge Lake; GORGE2 = Gorge Dam forebay.
Samples measured below the quantification limit are reported as ND.
Sampling was not completed in November 2021 due to flooding downstream preventing access to Gorge Lake.
Sampling was not completed in December 2021 due to snow and ice safety concerns at boat launches.

A Secchi disk was used to measure water transparency in Gorge Lake during vertical profiles conducted in 2022 (Figure 5.1-61). Secchi depth ranged from a minimum of about 1.5-m at both sites to a maximum of about 5.5-m (bottom) at GORGE1 and about 6-m at GORGE2 in September.

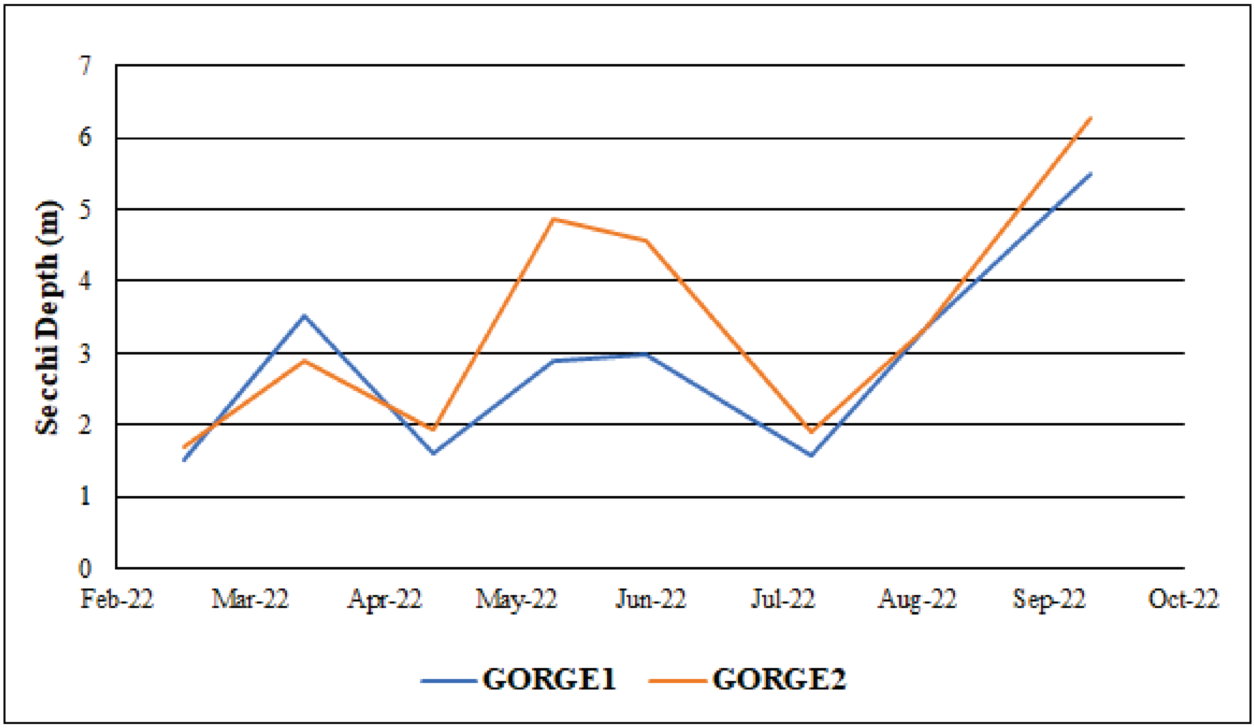



**Figure 5.1-61. Water transparency as measured with a Secchi disk in Gorge Lake (February-September 2022).**

### 5.1.3.5 Total Dissolved Gas

Continuous monitoring of TDG in Gorge Lake below Diablo Dam, across the reservoir from the Diablo Powerhouse outflow (GORGE3, see map in Attachment A), and in the Gorge Dam forebay (GORGE4) began in September 2021. The sonde installed below Diablo Dam is anchored to a fixed substrate, so logging depth varies with water surface elevation. The sonde in the forebay is attached to the floating log boom and maintains a depth of approximately 3-m (9.8 ft) regardless of water surface elevation. Both sondes record TDG at 30-minute intervals.

TDG data collected in Gorge Lake from September 9–October 5, 2021 and corresponding flow data from Diablo Powerhouse during the same period are presented in Figure 5.1-62. TDG greater than 110 percent saturation was observed below Diablo Dam on September 18 (113 percent) and again on September 30 (115 percent). However, values in the Gorge Dam forebay remained near 106 percent saturation throughout this period. Closer examination of the September 18 and September 30 data below Diablo Dam suggests that periods of higher TDG concentrations correspond to reduced flows at Diablo Powerhouse (less than approximately 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 5.1-63 and 5.1-64). Elevated TDG levels below Diablo Dam appear to be linked to the operation of an air admission system on two turbines at the Diablo Powerhouse (U31 and U32). Both units have systems in place that admit air from about 30-90 MW, allowing the units to run more smoothly and improve operational efficiency at low generation (Gordon 2021).

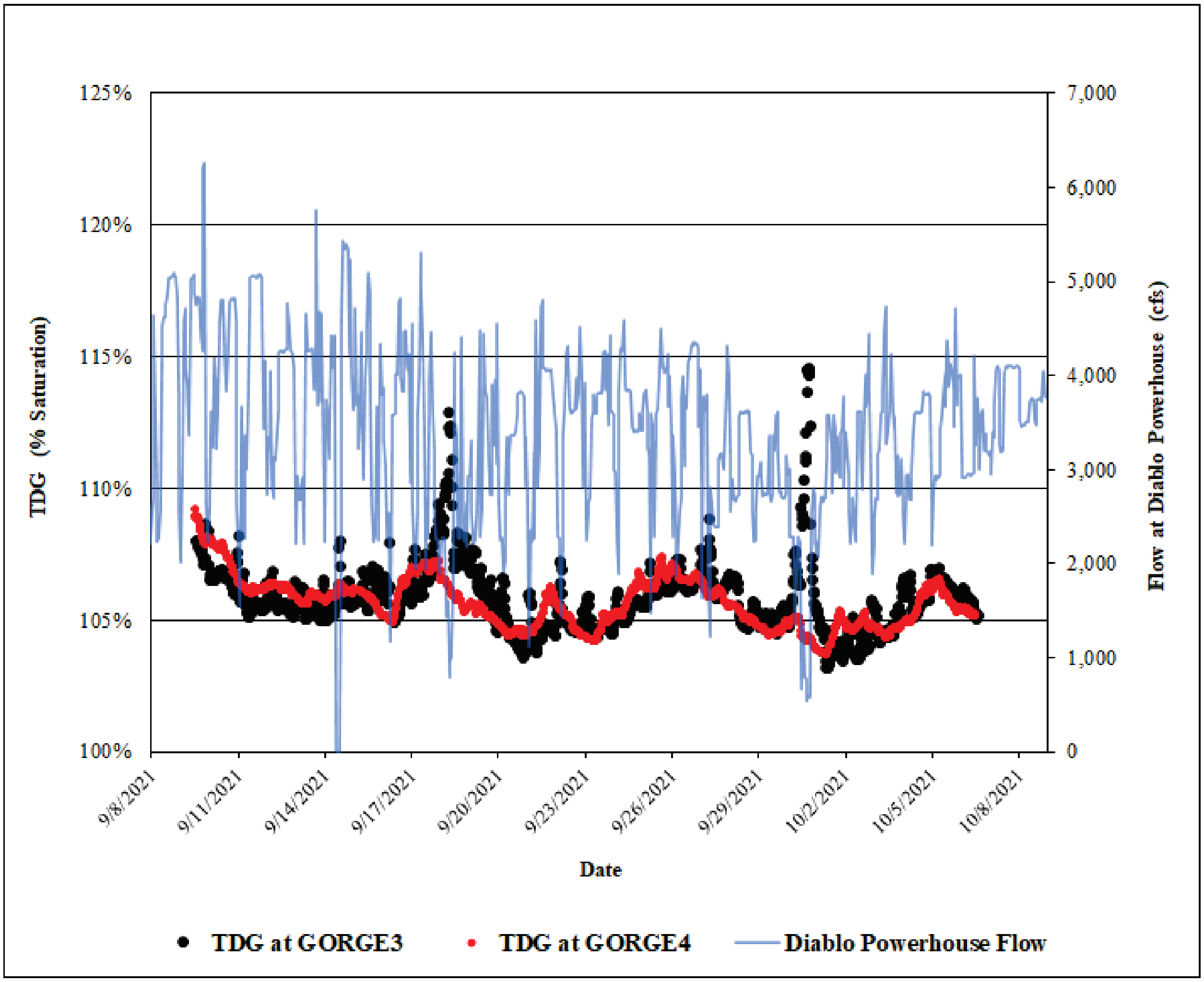



**Figure 5.1-62. TDG at Gorge Lake sites (below Diablo Dam, GORGE3 and Gorge Dam forebay, GORGE4) and flow at Diablo Powerhouse (cfs) (September-October 2021).**

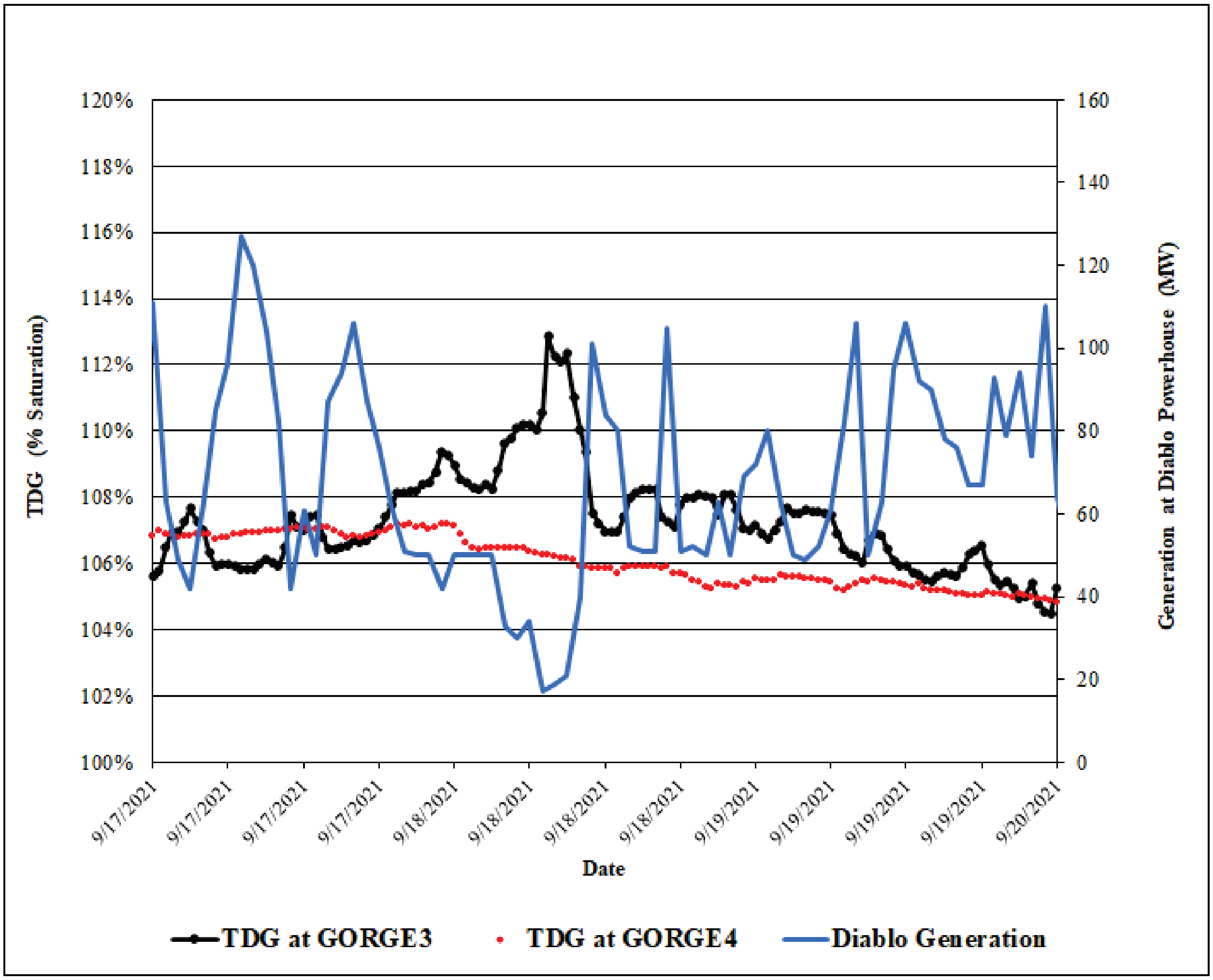



**Figure 5.1-63.** **TDG at Gorge Lake sites (below Diablo Dam, GORGE3 and Gorge Dam forebay, GORGE4) and generation at Diablo Powerhouse (MW) (September 17-September 20, 2021).**

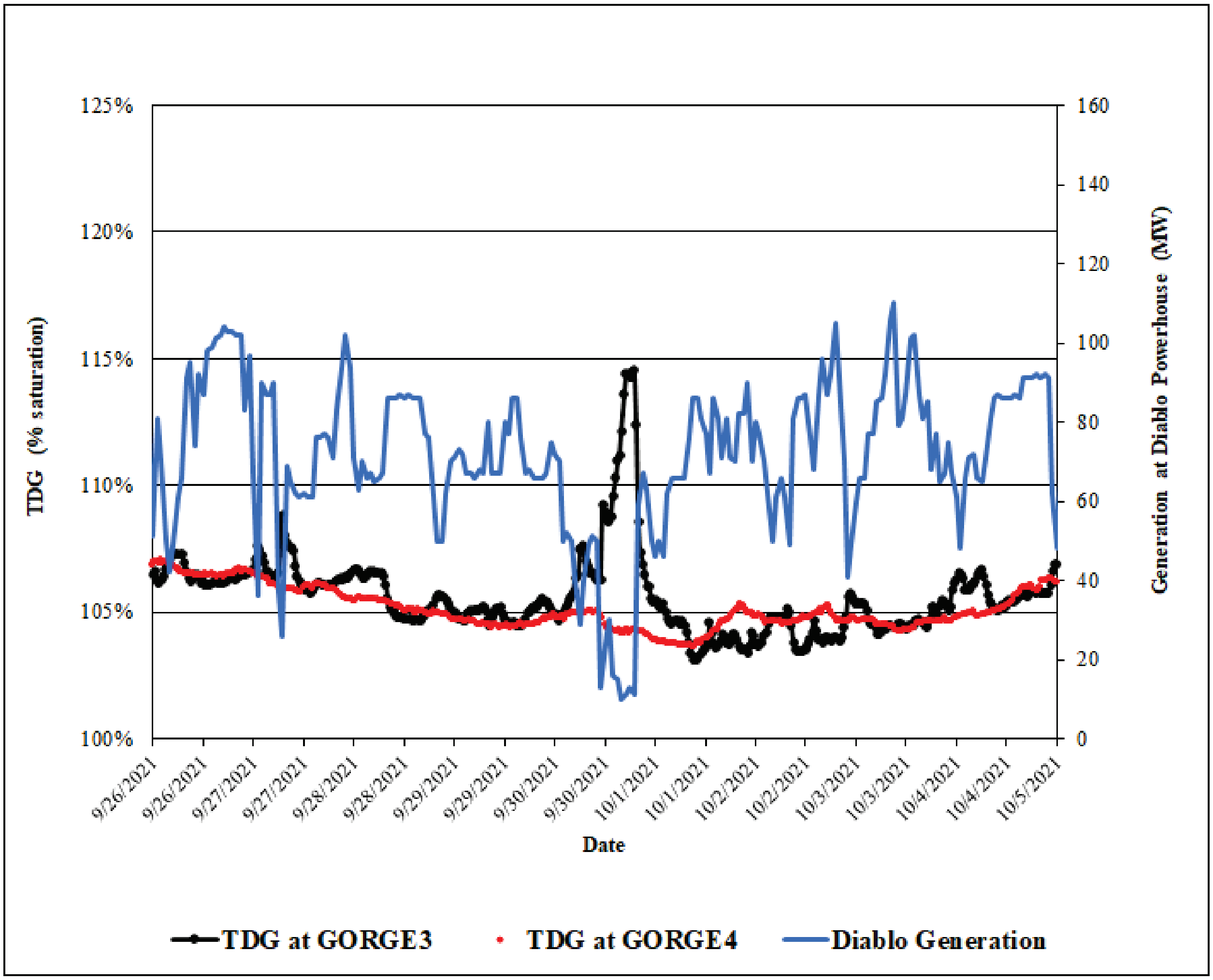
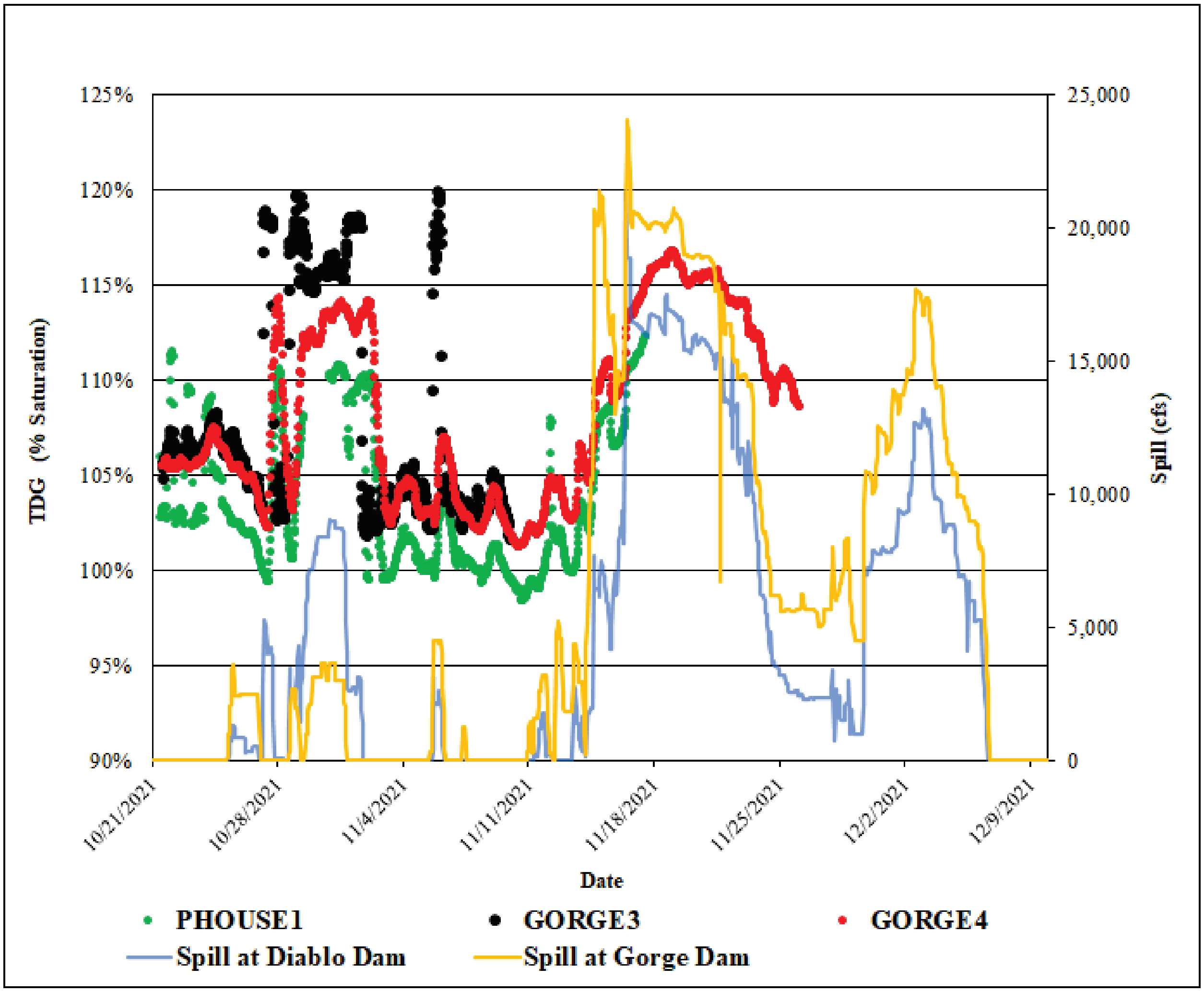



**Figure 5.1-64. TDG at Gorge Lake sites (below Diablo Dam, GORGE3 and Gorge Dam forebay, GORGE4) and generation at Diablo Powerhouse (MW) (September 26–October 5, 2021).**

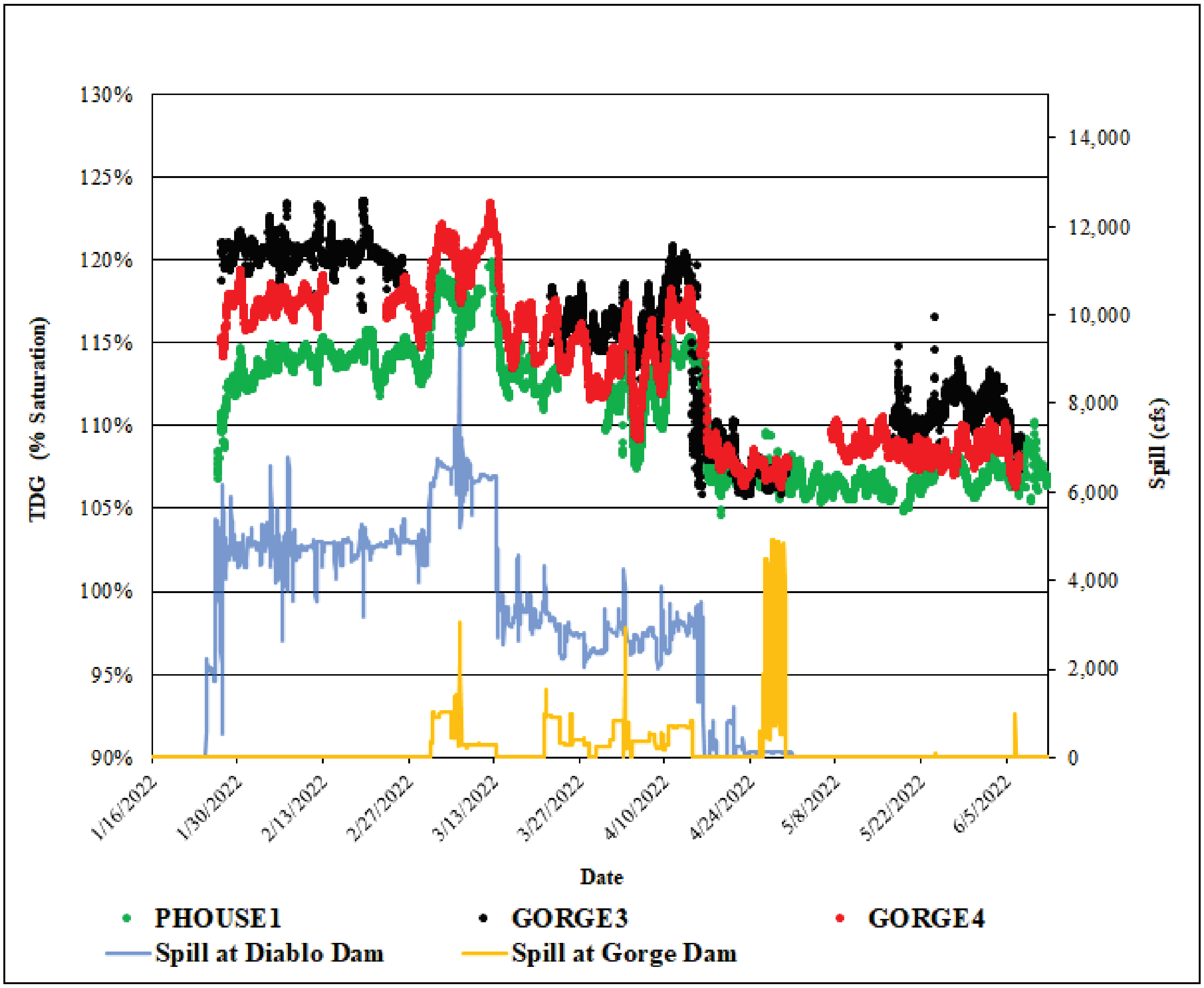
TDG monitoring continued below Diablo Dam (GORGE3), in the Gorge Dam forebay (GORGE4), and below Gorge Powerhouse (PHOUSE1) during October-December 2021, a period that included multiple spill events at both Gorge and Diablo Dam. TDG values at all three monitoring sites closely tracked spill, reaching 120 percent saturation at GORGE3 on November 6 and 117 percent saturation at GORGE4 on November 19 (Figure 5.1-65). TDG levels at Gorge Powerhouse also exceeded 110 percent saturation at times but were typically between 98 and 110 percent saturation during this period. Maximum TDG at GORGE4 occurred during a week-long spill in mid-November 2021. Flows at the USGS Newhalem gage (12178000) at this time reached 34,800 cfs on November 16, 2021.




Note: Sampling data not available for GORGE3 after November 10, 2021, GORGE4 after November 26, 2021, and PHOUSE1 after November 17, 2021 due to spill-related access issue resulting in battery loss.

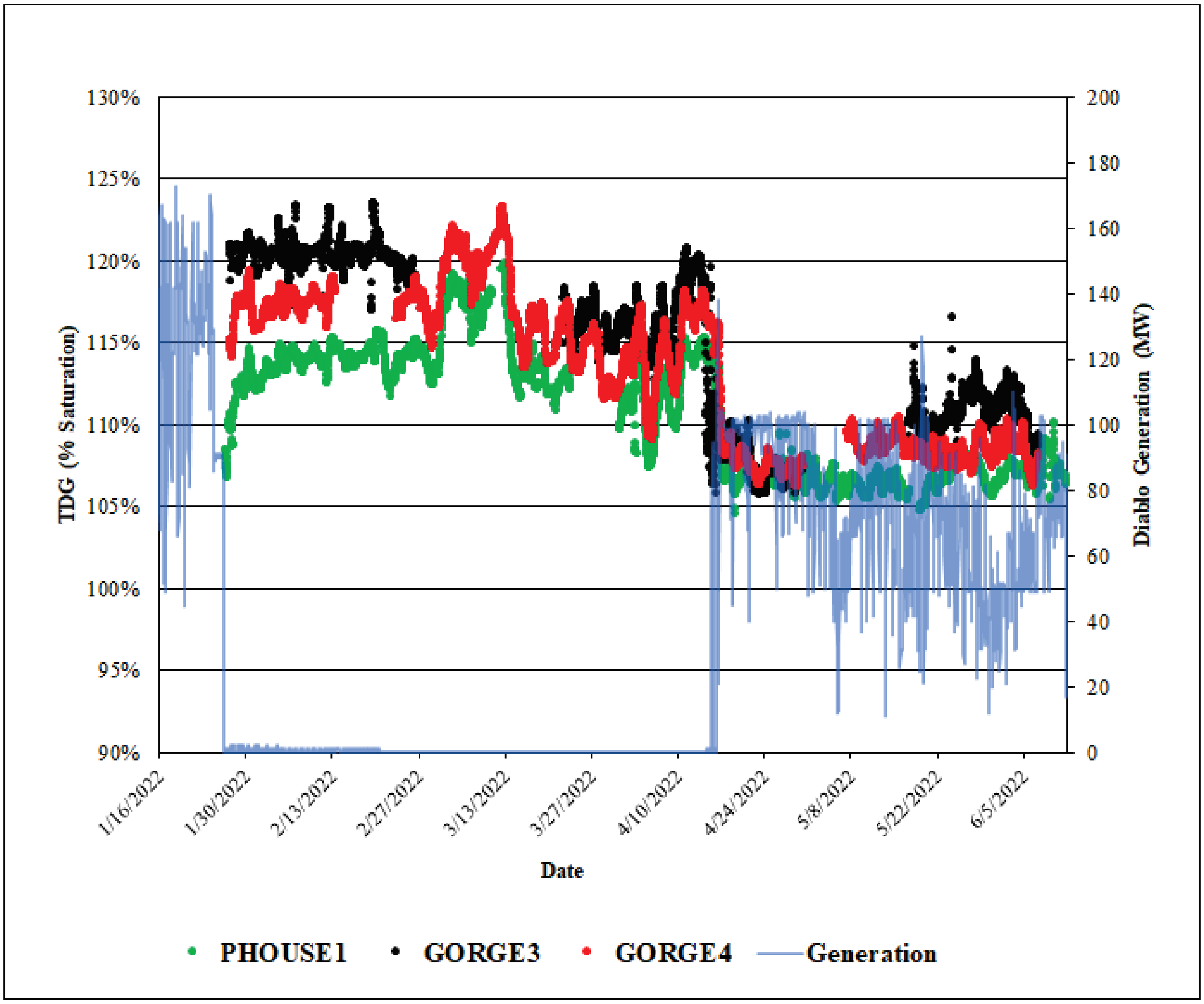
**Figure 5.1-65. TDG at Gorge Lake sites (below Diablo Dam, GORGE3 and Gorge Dam forebay, GORGE4), Gorge Powerhouse (PHOUSE1), and spill at Diablo and Gorge Dams (cfs) (October 21-December 9, 2021).**

Data collected in 2022 indicate that spill at Diablo Dam continued to cause elevated TDG at the Diablo Powerhouse (GORGE3) and Gorge Powerhouse forebay (GORGE4) sampling locations (Figures 5.1-66 and 5.1-67). TDG levels reached 123 percent saturation on February 19, 2022 and again on March 12, 2022. In addition, TDG measured at Gorge Powerhouse tailrace (PHOUSE1) reached 120 percent saturation on March 13, 2022, apparently as a result of spill at Diablo Dam. Gorge Dam was also spilling at that time, although at a lower volume; however, prior to that, elevated TDG (110-116 percent saturation) occurred when spill was released only at Diablo Dam. Further, in late April 2022, no increase was seen in TDG at PHOUSE1 when spill at Gorge Dam was approximately 5,000 cfs (Figure 5.1-66).




Note: Sampling data not available from GORGE3 from February 26, 2022 to March 22, 2022 due to weather-related access issue resulting in battery loss. Sampling data not available from GORGE3 April 30, 2022 to May 1, 2022 due to equipment failure. Sampling data not available from GORGE4 from April 30, 2022 to May 7, 2022 due to equipment failure.

**Figure 5.1-66.** **TDG at Gorge Lake sites (below Diablo Dam, GORGE3 and Gorge Dam forebay, GORGE4) and at Gorge Powerhouse tailrace (PHOUSE1), and spill at Diablo and Gorge Dams (cfs) (January 16-June 7, 2022).**



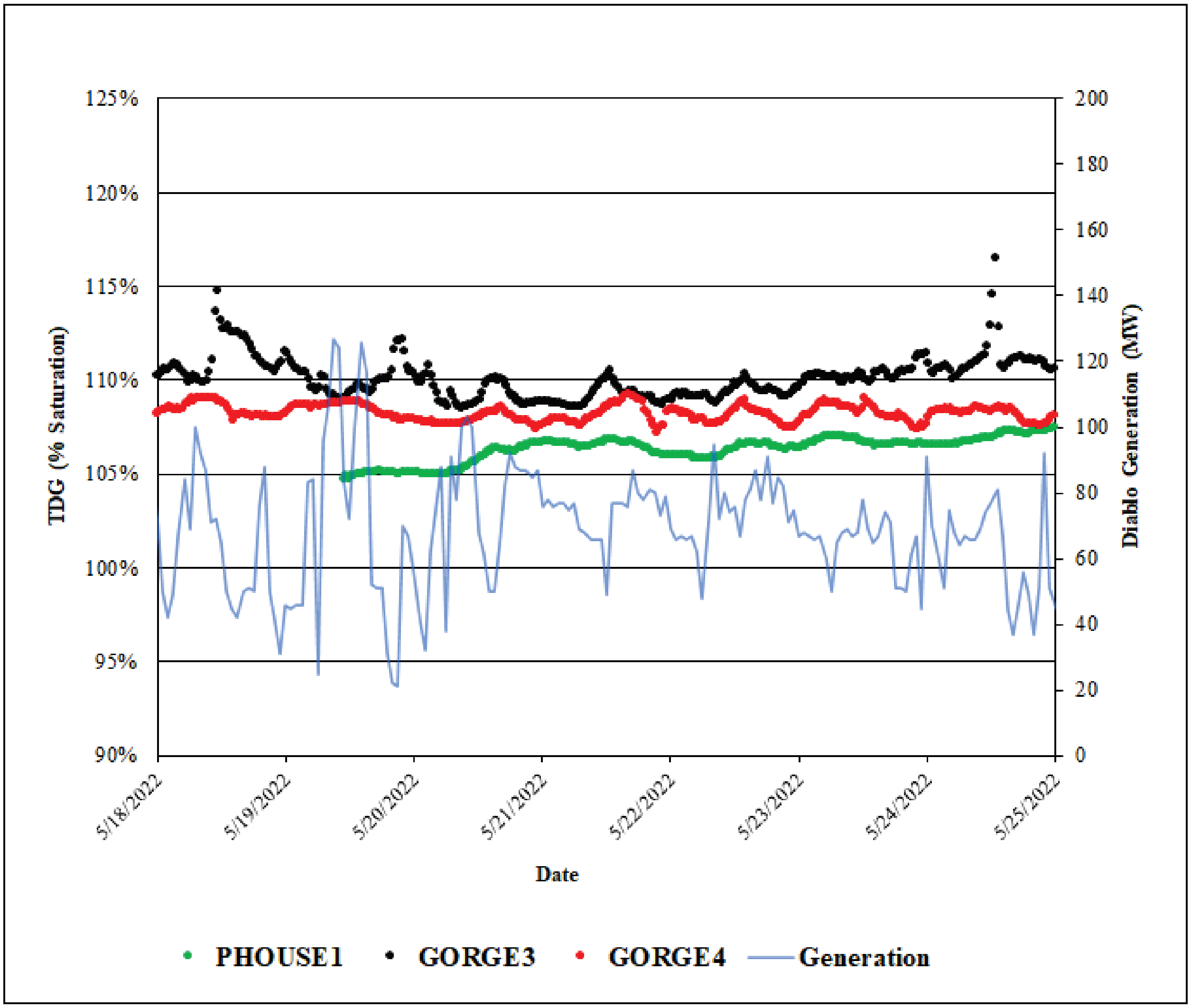

Notes: Sampling data not available from GORGE3 from February 26, 2022 to March 22, 2022 due to weather-related access issue resulting in battery loss. Sampling data not available from GORGE3 April 30, 2022 to May 1, 2022 due to equipment failure. Sampling data not available from GORGE4 from April 30, 2022 to May 7, 2022 due to equipment failure.

**Figure 5.1-67. TDG at Gorge Lake sites (below Diablo Dam, GORGE3, and Gorge Dam forebay, GORGE4) and at Gorge Powerhouse tailrace (PHOUSE1), and generation at Diablo Dam (cfs) (January 16-June 7, 2022).**

Elevated TDG at GORGE3, GORGE4, and PHOUSE1 sites persisted from mid-January through most of April 2022, with levels remaining above 110 percent. Diablo Powerhouse was offline for a period that corresponded closely with measurements of elevated TDG at all three monitoring sites; levels dropped quickly when Diablo Powerhouse resumed operation and spill ceased in mid-April 2022.

The operational effects on TDG that were observed in 2021 (i.e., effects of operating an air admission system on U31 and U32) were also seen in 2022: increased TDG at GORGE3 corresponded to periods of reduced generation from May 18-May 25 (Figure 5.1-68), and later in August (August 15-23; Figure 5.1-69). In both periods, reduction in generation to less than roughly

30-40 MW, or approximately 1,000 cfs caused TDG to exceed 110 percent saturation at GORGE3. Observed operational effects were of limited duration, i.e., on the order of hours, and, in contrast to spill effects, were not observed down-reservoir at GORGE4 or PHOUSE1.




Notes: Sampling data not available for PHOUSE1 from May 18, 2022 through May 19, 2022 due to battery loss.

**Figure 5.1-68. TDG at Gorge Lake sites (below Diablo Dam, GORGE3 and Gorge Dam forebay, GORGE4) and at Gorge Powerhouse tailrace (PHOUSE1), and generation at Diablo Dam (cfs) (May 18-25, 2022).**

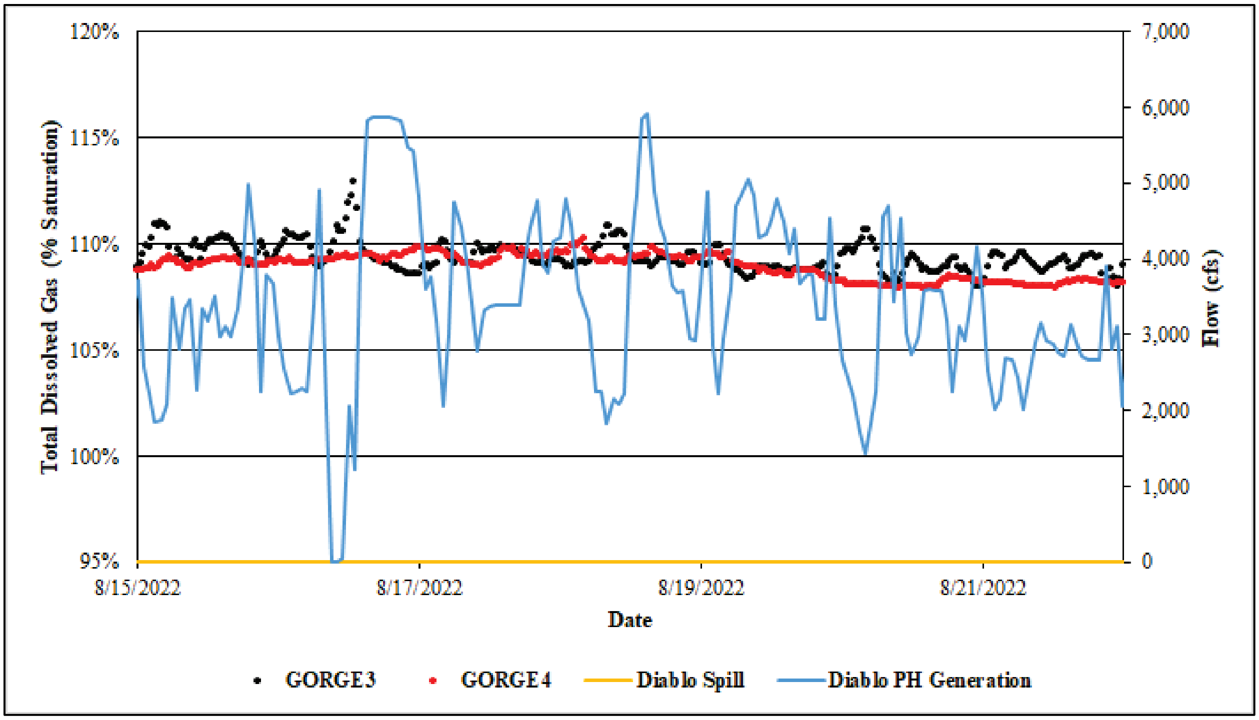



**Figure 5.1-69. TDG at Gorge Lake sites (below Diablo Dam, GORGE3 and Gorge Dam forebay, GORGE4) and at Gorge Powerhouse tailrace (PHOUSE1), and generation at Diablo Dam (cfs) (August 15-22, 2022).**

### 5.1.3.6 Nutrients and Productivity

Monthly sample collection at Gorge Lake for nutrients and productivity began in May 2022 and is ongoing. Results from May through September for Gorge Lake and Stetattle Creek are presented below (Table 5.1-17). Constituents measured include nutrients, carbon, chlorophyll *a*/pheophytin *a*, alkalinity, and phytoplankton. Similar to results reported for Ross and Diablo, laboratory analytes that were reported to be between the MDL and PQL, thus detected as non-zero but below the PQL, were flagged as J (i.e., should be considered estimated values).

Levels of carbon (CBOD, DOC, TOC, and TIC) near the downstream end of Gorge Lake (GORGE7) and Stetattle Creek (STET1) were generally low (less than 1 mg/L) indicating low productivity within the system. Similar to Ross and Diablo lakes, ammonium ($NH_3$-N) and orthophosphate ($PO_4^{-3}$) were largely below the PQL, while nitrate ($NO_x$) was typically detectable at or just above the PQL. Chlorophyll *a* (Chl *a*), an index of algal biomass and primary productivity, was at or below 0.6 µg/L during all sampling events. Phosphorus (TP) levels were typically below detection and alkalinity (ALK) was also low, less than 25 mg of calcium carbonate per L ($CaCO_3$ /L). Phytoplankton data will be analyzed when the complete set of phytoplankton taxonomic data is available. Similar to Ross and Diablo lakes, levels of nutrients and chlorophyll *a* concentrations in Gorge Lake indicate oligotrophic conditions.

**Table 5.1-17. Nutrients, chlorophyll a, and carbon measurements at Gorge Lake and Stetattle Creeks (May-September 2022).**

| Date | Site ID | Turb (NTU) | $NH_3$-N (mg/L) | $NO_x$ (mg/L) | TKN (mg/L) | $PO_4^{-3}$ (mg/L) | TP (mg/L) | Chl *a* (µg/L) | Pheo *a* (µg/L) | CBOD (mg/L) | DOC (mg/L) | TOC (mg/L) | TIC (mg/L) | ALK (mg $CaCO_3$/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| May 17, 2022 | GORGE7 | 1.2 | 0.009J | 0.05 | .079J | 0.0044J | 0.0028J | <0.1 | <0.1 | 1 | 0.98 | 1.13 | 6.15 | 26 |
| | STET1 | 0.35 | ND | 0.07 | ND | ND | ND | ND | ND | 3 | 0.89 | 0.83 | 1.38 | 4.8 |
| Jun 7, 2022 | GORGE7 | 1.6H1 | ND | 0.06 | ND | 0.004J | 0.005J | 0.235 | 0.161 | 2 | 0.88 | 0.87 | NM | 17.7 |
| | STET1 | 0.18H1 | ND | 0.03 | ND | ND H1 | 0.0045J | 0.643 | 0.307 | 1 | 0.76 | 0.76 | NM | 4.1 |
| Jul 6, 2022 | GORGE7* | 2.5 | NM | 0.04 | ND | 0.0043H1 | NM | 0.192 | 0.176 | 1.19 | 0.82 | 0.99 | 4.81 | 19.4 |
| | STET1 | 1.1 | ND | 0.03 | ND | 0.0062J | 0.0070 J | 0.193 | 0.15 | ND | 0.86 | 0.84 | NM | 12.2 |
| Aug 9, 2022 | GORGE7 | 1.2 | ND | 0.05 | ND | 0.0096J | 0.0024 J | 0.138 | 0.112 | ND | 0.76 | 0.73 | NM | 23.6 |
| | STET1 | ND | 0.009 | 0.03 | ND | 0.0044J | ND | 0.277 | 0.331 | ND | 0.32 | 0.39 | NM | 3.9 |
| Sep 15, 2022 | GORGE7 | 0.86 | ND | 0.03 | ND | 0.0076J | ND | NR | NR | <1 | 0.72 | 0.72 | NM | 24.8 |
| | STET1 | 0.79 | ND | 0.04 | 0.16J | 0.0073J | 0.0027J | NR | NR | <1 | 0.79 | 0.75 | NM | 25.1 |

Notes: Turb = turbidity; $NH_3$-N = ammonia; $NO_x$= Nitrate+nitrite N; TKN=Total Kjeldahl N; $PO_4^{-3}$ = orthophosphate; TP = total phosphorus; Chl *a* = chlorophyll *a;* Phe *a* = Pheophytin *a;* CBOD = carbonaceous biochemical oxygen demand; DOC = dissolved organic carbon; TOC = total organic carbon; TIC = total inorganic carbon; ALK = alkalinity.

J qualifier assigned by Edge Lab indicates <PQL; H1=analysis performed beyond recommended holding time; ND=less than method detection; NM = not measured; * = sample date July 14, 2022; NR = not yet reported by the laboratory.

#### 5.1.3.7 Benthic and Drifting Macroinvertebrates

This section presents available BMI data for Gorge Lake and Stetattle Creek, including PONAR sampling results for Gorge Lake in June and July 2022 and kicknet samples in June, July, and August 2022. Drift sample results will be analyzed when the complete set of taxonomic data is available. As described in Section 4.1.2, both PONAR and drift samples from Gorge Lake were collected in replicate.

**Reservoir Benthic Sampling**

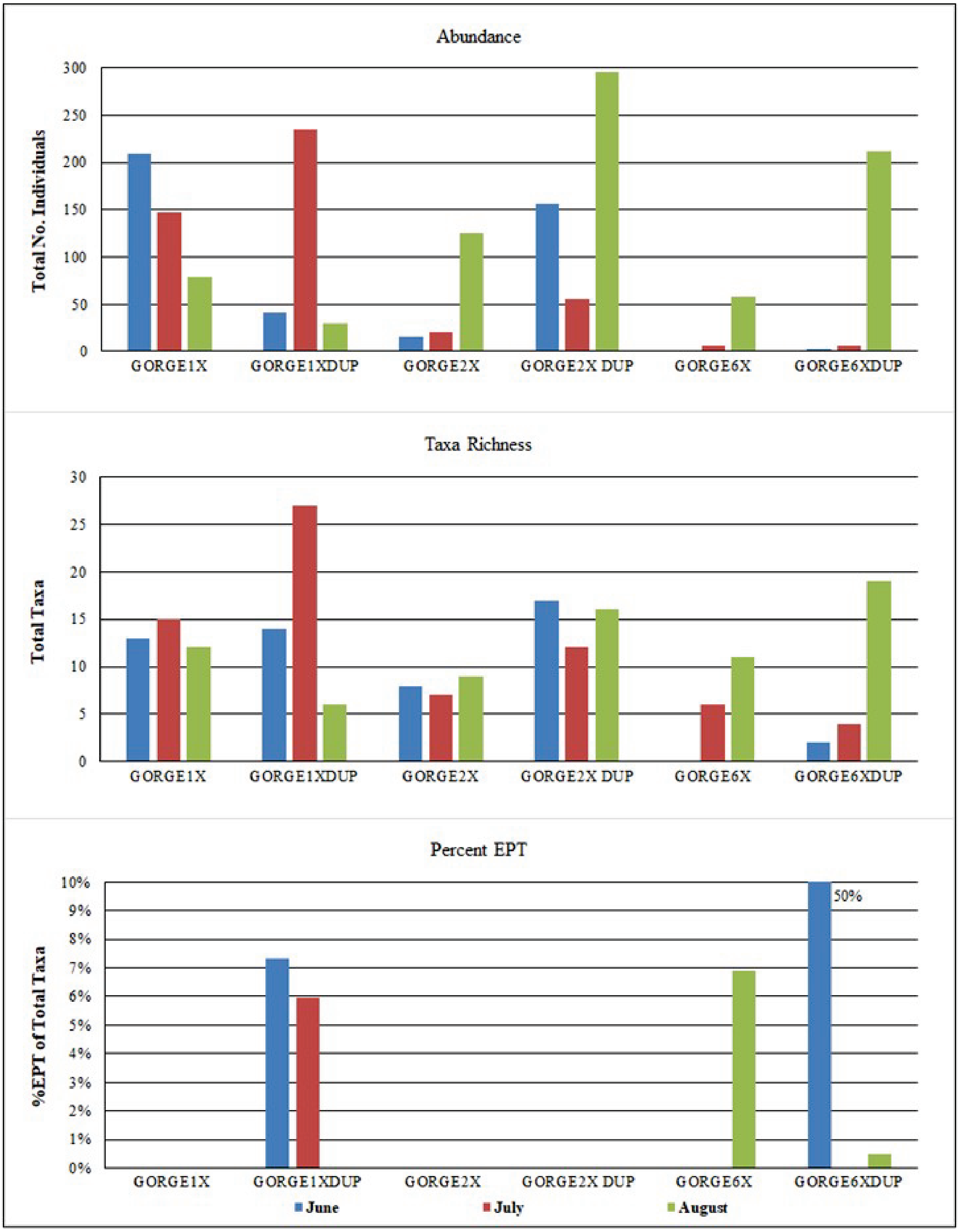
PONAR sampling is reported for three sampling events; June, July, and August, at three Gorge Lake sites: GORGE1X, upstream from Diablo Powerhouse; GORGE2X, at Gorge Dam; and GORGE6X, Gorge Lake upstream of the Stetattle Creek confluence. Gorge Lake PONAR samples held far fewer BMI than riverine sites. In June at GORGE6X, no benthic invertebrates were counted, and, with one exception (Gorge1X in July), fewer than 20 taxa were present in Gorge Lake benthic samples (Figure 5.1-70). EPT taxa were also comparatively low in abundance, less than 10 percent with the exception of GORGE6X in June (Figure 5.1-70). Due to low numbers of individuals present, none of the Gorge PONAR samples required subsampling, i.e., 100 percent of each sample was counted. Dominant taxa present in the samples included nematodes, *Parakiefferiella* sp. And *Parametriocnemus* (chironomids), and oligochaete worms (*Aulodrilus pluriseta*, and a lumbriculid worm).

Functional group composition for Gorge Lake PONAR samples is shown in Figure 5.1-71. There were fewer functional groups represented in Gorge Lake benthic samples than kicknet samples collected at Stetattle Creek. BMI identified were primarily gatherers, predators, or filterers. For the three months reported (June, July, and August), functional group composition was most consistent at the deepest Gorge Lake site (GORGE2X at Gorge Dam). Further analysis of Gorge Lake PONAR samples will be completed when the full set of taxonomic data are available.

**Kicknet Sampling**

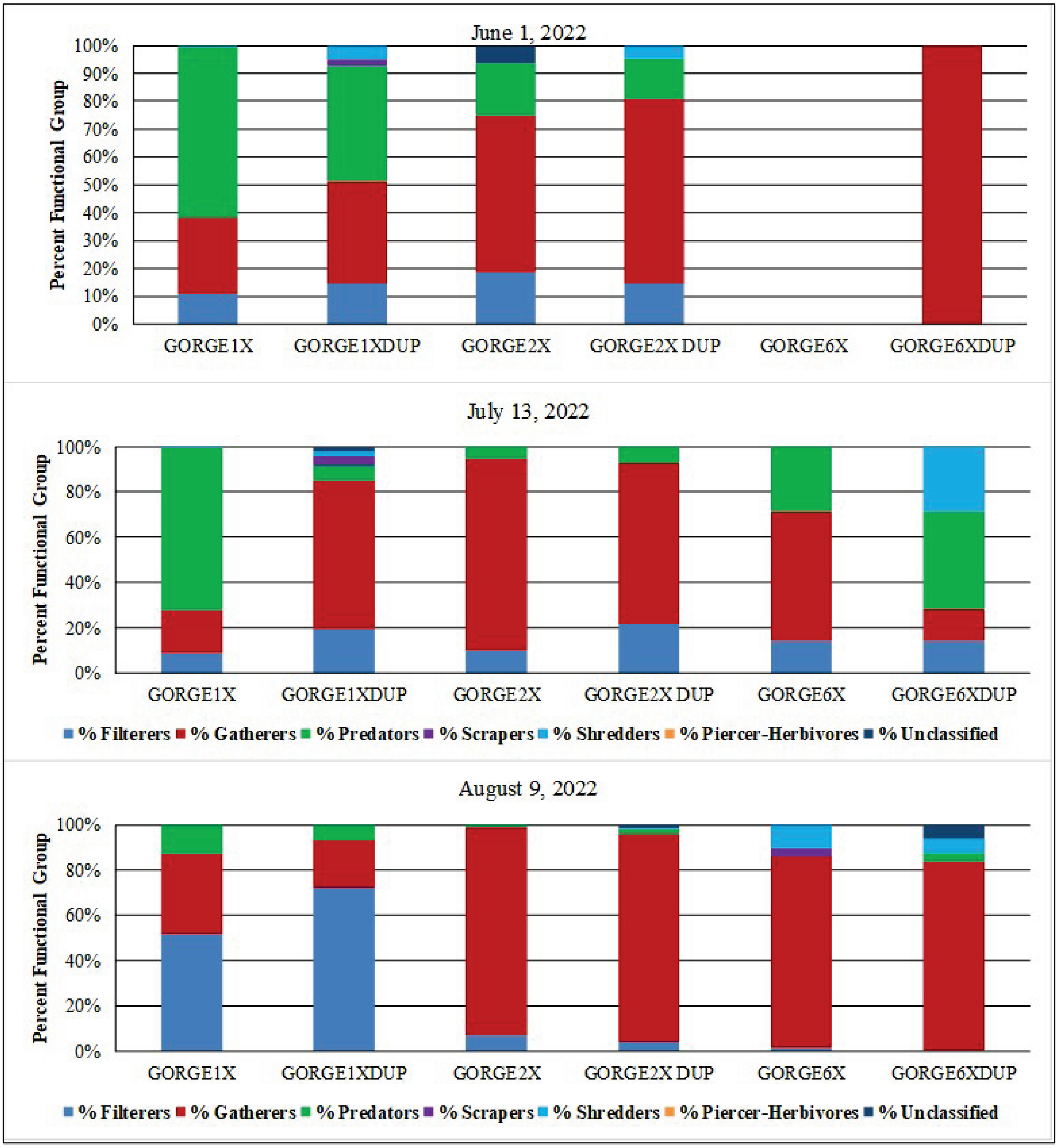
Results of kicknet sampling in Stetattle Creek, a tributary to Gorge Lake, are shown below for June, July, and August 2022. As discussed in Section 4.1, reported metrics include abundance, taxa richness, percent EPT composition, and functional group composition (Figures 5.1-72 and 5.1-74). Abundance and taxa richness (total taxa identified) in Stetattle Creek were similar among the three monitoring events; between 300 and 500 individuals per $m^2$ were counted and 36-38 taxa identified. For comparison, an average of 44 taxa were reported for sites downstream of Gorge Dam (Section 5.3.8) for monitoring events in August 2021 and from May through August 2022. Percent EPT composition for Stetattle Creek ranged from 71 percent in June to 49 percent in July (2022). Average percent EPT composition for all main channel sites downstream of Gorge Powerhouse (Section 5.3.8) was 35 percent.

Functional group composition for Stetattle Creek samples from June through August 2022 is shown below (Figure 5.1-73). Group composition in June was dominated by BMI classified as gatherers (32 percent) and scrapers (42 percent). Gatherers also dominated in July and August (49 percent and 37 percent, respectively). The most notable change in the BMI community at Stetattle Creek was the reduction in scrapers from June to July and August (12 and 18 percent, respectively), likely a function of greater biomass and/or quality of periphytic algae as a food source in early spring.




Note: No individuals were present in the GORGE6X sample in June 2022.

**Figure 5.1-70. Abundance (number of individuals per PONAR sample) (top), taxa richness (middle), and percent EPT composition (bottom) for Gorge Lake BMI PONAR samples; GORGE1X = upstream of Diablo Powerhouse, GORGE2X = at Gorge Dam, GORGE6X = upstream of Stetattle confluence (June-August 2022) (DUP = duplicate).**




Note: No individuals were present in the GORGE6X sample in June 2022.

**Figure 5.1-71. Functional group composition in PONAR samples from Gorge Lake; GORGE1X = upstream of Diablo Powerhouse, GORGE2X = at Gorge Dam, GORGE6X = upstream of Stetattle confluence (June-August 2022) (DUP = duplicate).**

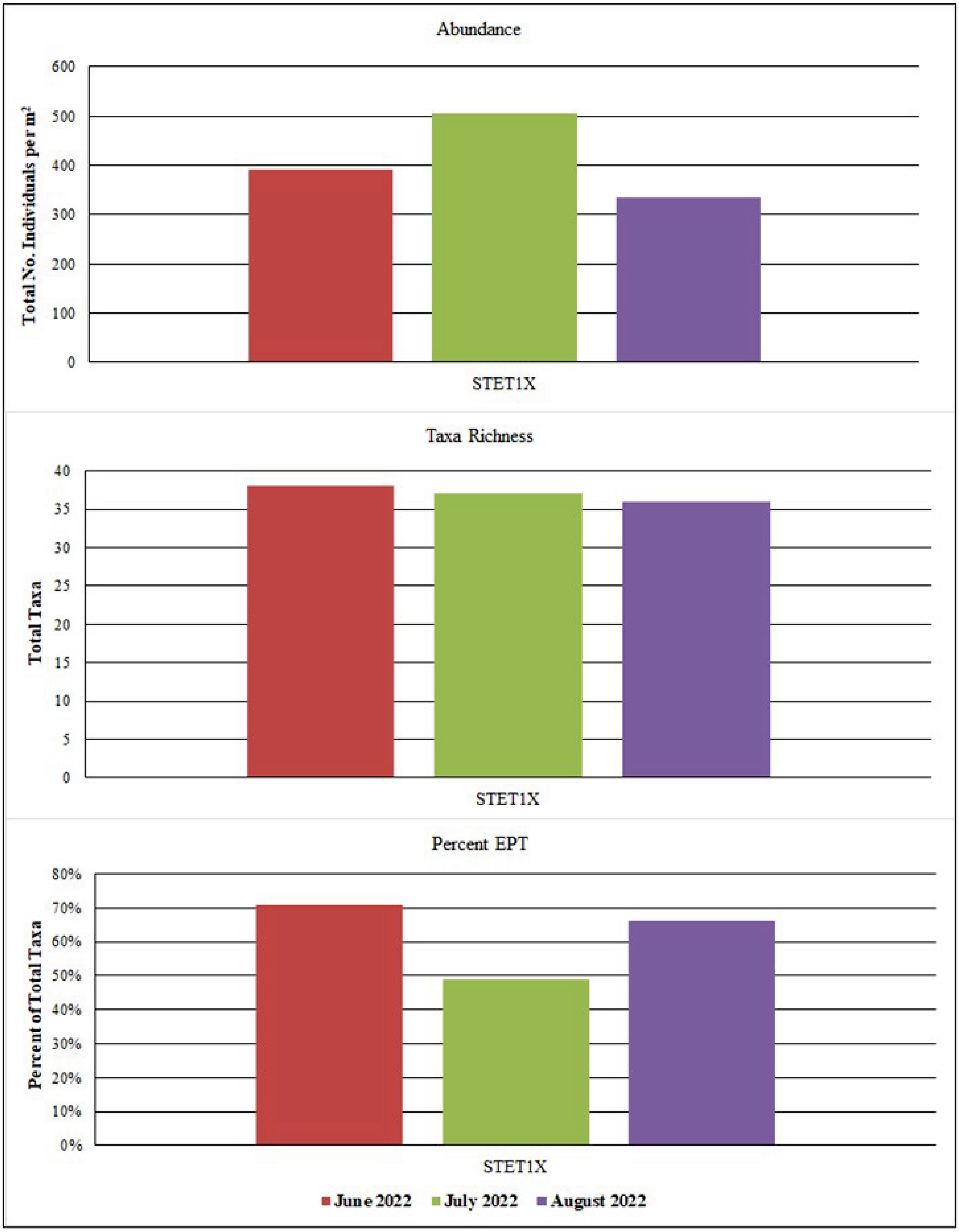



**Figure 5.1-72. Abundance (top), taxa richness (middle) and percent EPT composition (bottom) for Stetattle Creek BMI kicknet samples (June-August 2022).**

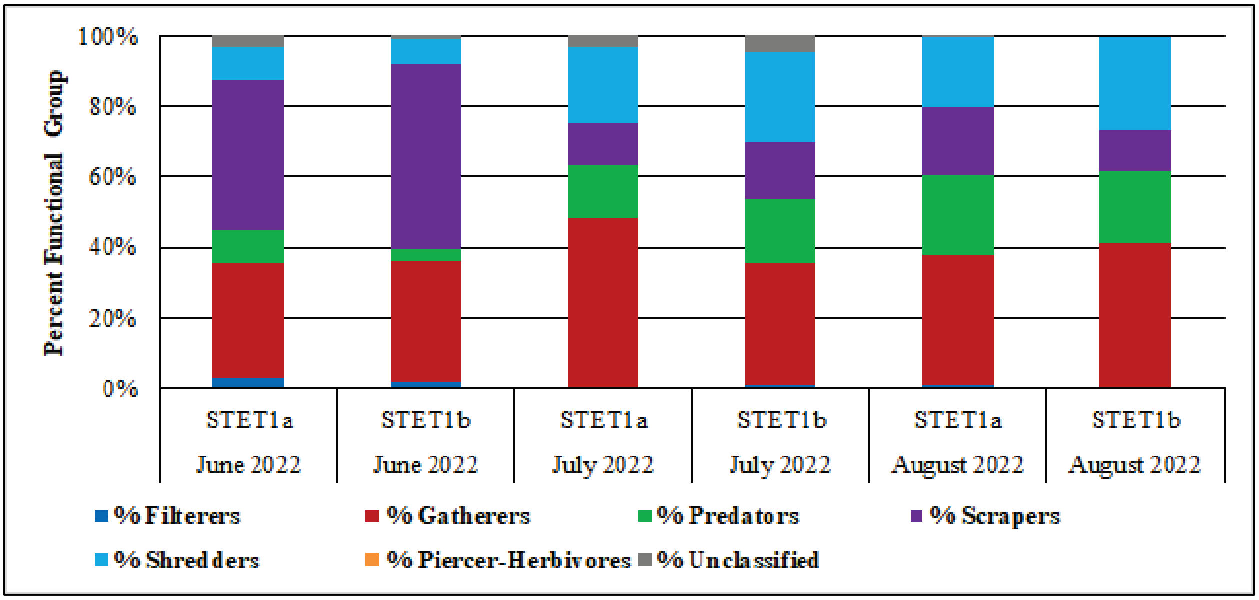



**Figure 5.1-73. Functional group composition at Stetattle Creek (June-August 2022).**

### Drift Sampling

In addition to kick samples, discussed above, paired drift samples have been collected at Stetattle Creek at 4-6 week intervals, beginning June 1, 2022. Drift data will be analyzed when the complete set of drift taxonomic data is available.

#### 5.1.3.8 QA/QC

As noted in Section 4.2, a duplicate sample was collected during each field visit, though not consistently on Gorge Lake. Diablo and Gorge lakes were typically visited during the same sampling event; thus a duplicate was collected at a randomly selected site and depth at either Gorge Lake or Diablo Lake immediately following routine sample collection. Duplicates were measured for turbidity and TSS, and their RSD calculated to assess sample variability in the field (Table 5.1-18). 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. Samples for analysis of nutrients and productivity in Gorge Lake were typically collected during the same sampling event as downstream of Gorge Powerhouse, and duplicate precision is discussed in Section 5.3.9.

**Table 5.1-18. Results of field duplicate measurements of turbidity and total suspended solids at Gorge Lake (June 2021-September 2022).**

| Date | Site | Turbidity (NTU) | | | TSS (mg/L) | | |
|---|---|---|---|---|---|---|---|
| | | R | D | RSD | R | D | RSD |
| Aug-2021 | GORGE2 – 1-m | 2.7 | 2.5 | 5.4 | 2 | 2 | 0.0 |
| Oct-2021 | GORGE2 – 5-m | 6.8 | 4.8 | 24.4 | 3 | 2 | 28.3 |
| Mar-2022 | GORGE2 – 5-m | 2.5 | 2.7 | 5.4 | ND | ND | ND |
| Apr-2022 | GORGE2 – 1-m | 0.88 | 0.86 | 1.6 | ND | ND | ND |
| Jul-2022 | GORGE1 – 1-m | 2.6 | 2.3 | 8.7 | 2.5 | 2.5 | 0.0 |

Notes: R = routine; D = Duplicate; RSD = (S*100)/mean; duplicate randomly assigned to either Diablo or Gorge Lake.

For turbidity, RSD values exceeded 5 percent in four of the five samples collected at Gorge Lake, TSS results were non-detectable for two of the five samples, and RSD values ranged from 0 to 28.3 percent in Gorge Lake. The latter reflect low TSS and a difference of only 1 mg/L between field and duplicate on both samples. Thus, while a violation of the QAPP RSD criteria, the impact on data quality and overall confidence in terms of accurately characterizing TSS and turbidity levels are deemed negligible.

Results of blank sample analyses were non-detectable for all TSS samples through September 2022. Detectable turbidity in blanks was reported for nine of 15 samples from June 2021 through September 2022 ranging from 0.1 to 0.6 NTUs.

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 in 2021. Other vertical profile parameters at both GORGE1 and GORGE2 were 100 percent complete in both 2021 and 2022. All vertical profile visits were conducted per the schedule outlined in the RSP except November 2021, when there was no access to the Project area due to flooding downstream, and December 2021, when it was not safe to use boat launches on Gorge Lake due to snow and ice.

Continuous monitoring of TDG in Gorge Lake began on September 9, 2021, later than the June start date specified in the RSP, due to supply chain limitations at the manufacturer. One data point was rejected from continuous monitoring of TDG at both GORGE3 and GORGE4 for 99.9 percent data completeness at both sites in 2021 (Table 5.1-19). Only five data points were rejected from continuous monitoring of TDG at GORGE3, and 10 data points were rejected from GORGE4 for 99.9 percent data completeness at both sites in 2022 (Table 5.1-19).

The high number of qualified data points for TDG is due to failed performance tests conducted in the field at an interval of approximately every three to four weeks. Performance tests occur over a limited amount of time and, if extended, it is expected that values would equalize and most if not all data points would be accepted.

In June 2022, following successive failure of performance tests for TDG, sondes at both GORGE3 and GORGE4 were removed from the field for a performance assessment, including an extended performance test against a calibrated unit in a stable environment. Both sondes passed the evaluation and were redeployed. To the extent possible, longer testing periods allowing for equilibration of test units are being conducted for the duration of the monitoring program. In addition, TDG membranes are replaced and sensors are calibrated after every performance test, regardless of pass/fail results, in order to maintain data quality.

**Table 5.1-19. Percent completion results for continuous TDG monitoring at Gorge Lake sites (September-October 2021, January-October 2022).**

| Parameter | Site ID | Accepted | Qualified | Rejected | Total Planned Results | Percent Complete |
|---|---|---|---|---|---|---|
| **2021** | | | | | | |
| TDG | GORGE3 | 1,249 | 0 | 1 | 1,250 | 99.9% |
| TDG | GORGE4 | 1,250 | 0 | 1 | 1,251 | 99.9% |
| **2022** | | | | | | |
| TDG | GORGE3 | 5,376 | 4,548 | 5 | 9,929 | 99.9% |
| TDG | GORGE4 | 2,515 | 8,465 | 10 | 10,990 | 99.9% |

As described in Section 4.1.6.1, percent saturation of TDG was calculated based on local barometric pressure recorded with an Onset Model S-BPB sensor and data logger installed at an upland location near BYPASS1, approximately 0.25 mile downstream of Gorge Dam. Pressure data from the Burlington Airport and a sensor nearby in the bypass reach (operated by Northwest Hydraulic Consultants, Inc.) were used to fill gaps in coverage due to logger malfunction during the summer of 2022. A sensitivity analysis was conducted to determine adequacy, i.e., acceptability of the replacement barometric pressure data by comparing readings made at the Burlington Airport and elsewhere in the bypass reach with the BYPASS1 sensor over a week-long period when all three were operational (June 17-23, 2022). Following application of a correction factor for the Burlington Airport data, average differences were under 0.5 percent for both replacement data sources.

Results of a comparison of routine and duplicate samples are shown below for abundance, taxa richness and percent EPT composition (Figure 5.1-76). Of these, variability was lowest for percent EPT composition, and higher than the 20 percent specified in the QAPP for abundance. RSD results for Stetattle Creek are based on three sampling events and are expected to decrease when the complete set of taxonomic data is available.

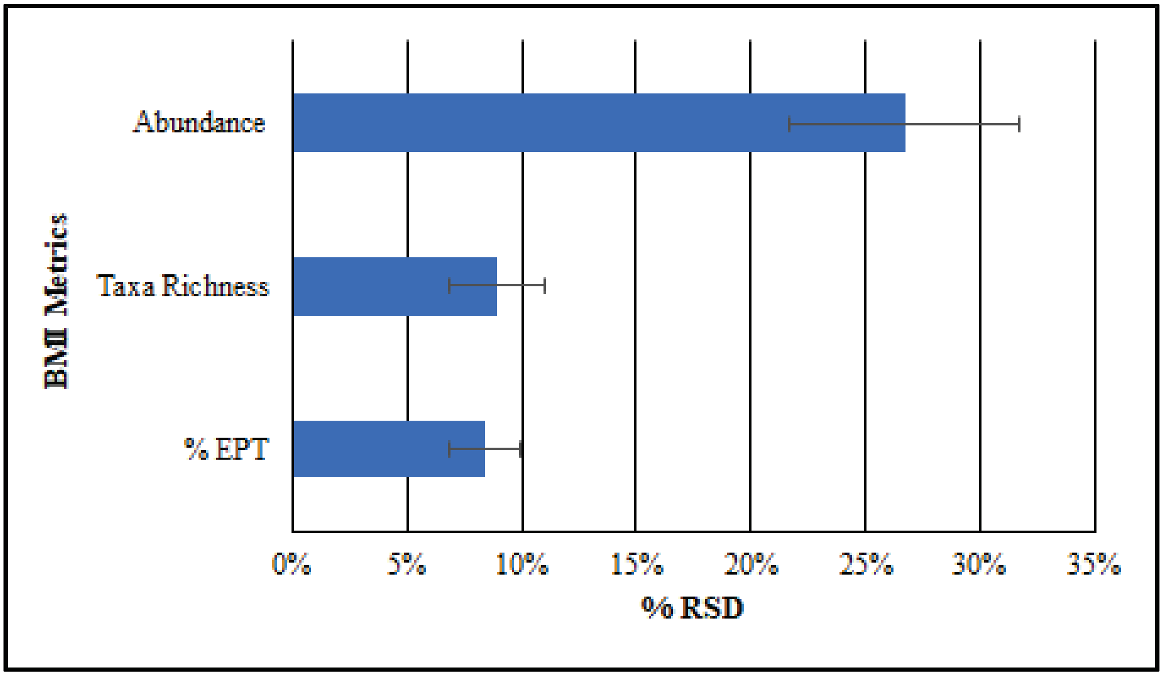



**Figure 5.1-74. Mean percent RSD for BMI metrics based on three kicknet sampling events in Stetattle Creek (June-August 2022). Error bars show standard error.**

## 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 ft NAVD 88 (718 ft CoSD) at BYPASS1 to approximately 490 ft NAVD 88 (483 ft CoSD) at PHOUSE1.

Monitoring at BYPASS1 and BYPASS3 sites began on January 28, 2021, and PHOUSE1 on February 11, 2021. Each site was accessed every 3 to 4 weeks for sonde maintenance, data transfer, and repositioning if a sonde 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.

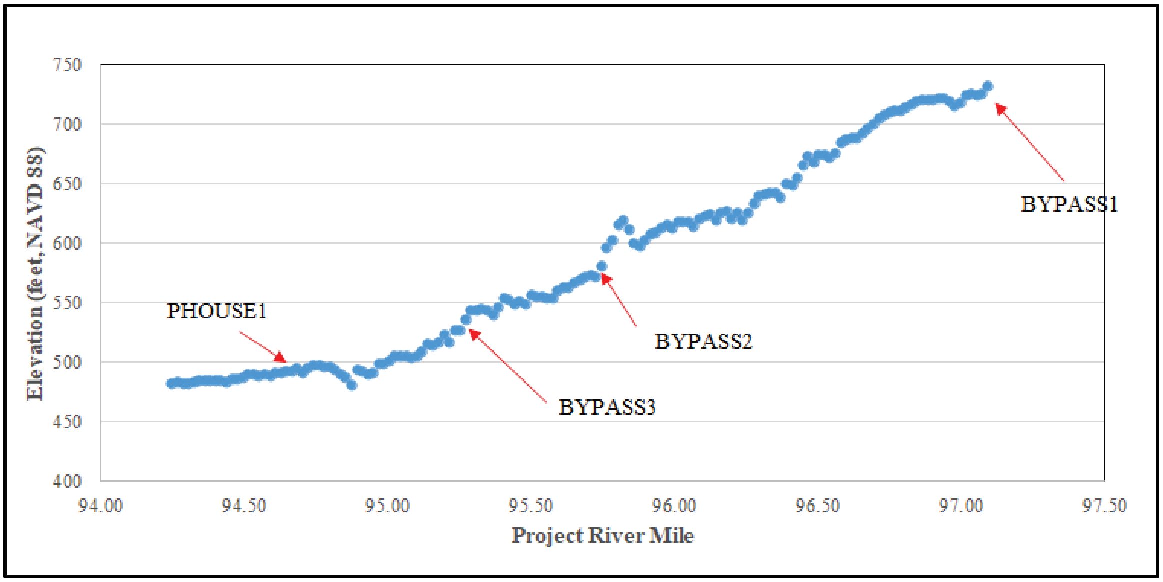



**Figure 5.2-1. Gorge bypass reach (BYPASS1-3) and Powerhouse (PHOUSE1) monitoring locations by Project River Mile and their elevations (ft NAVD 88).**

As described in Section 4.2, field personnel conducted mid-deployment performance checks of each sonde, 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 a recently calibrated sonde. Any differences in the readings were then used to calculate deviation thresholds. As discussed in Section 4.2, any sondes 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 5.2.8). Water quality data reported in this study report have complied with QAQC procedures. These data will be made available upon request.

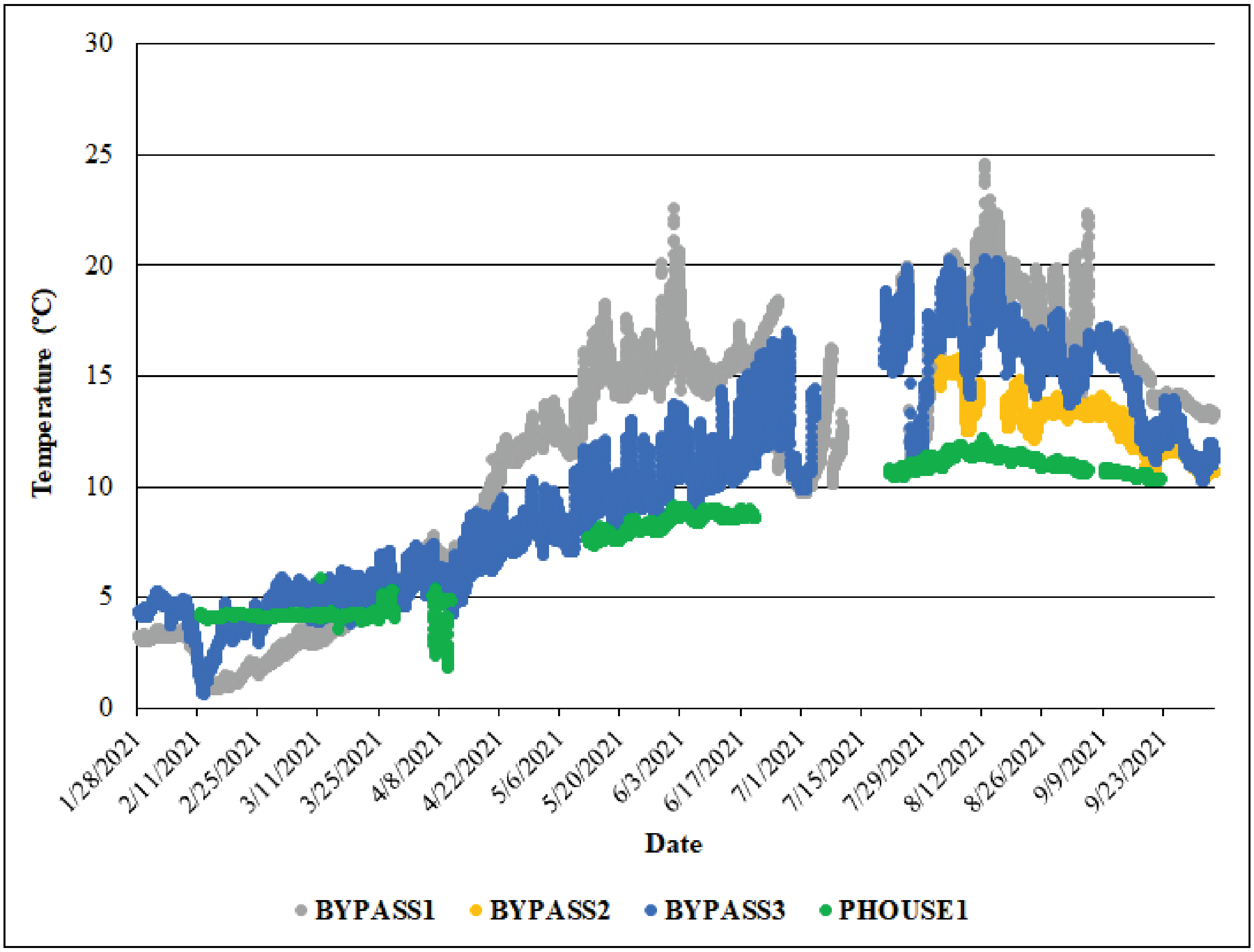
The three sondes monitoring water quality in the Gorge bypass reach were lost or damaged during high flows in winter 2021, and no data are available for these locations after the October 5, 2021 site visit. High flows precluded access to the PHOUSE1 sonde until January 2022; however, the sonde was recovered and continuous monitoring is ongoing. Monitoring in the Gorge bypass reach has transitioned to approximately monthly short-term (approximately 1 hour) deployments at BYPASS1 and BYPASS3.

### 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 in 2021 were, at times, substantially above normal based on data from the National Weather Service (NWS; 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). Normal 2021 and 2022 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 sondes located at the BYPASS1, BYPASS3, and PHOUSE1 sites were deployed early in 2021, whereas the BYPASS2 sonde 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.




Note: Sample data not available at PHOUSE1 from April 10, 2021 to May 12, 2021 because the unit was dewatered. Sample data not available at BYPASS1 from July 10, 2021 through July 22, 2021, at BYPASS3 from July 4, 2021 through July 20, 2021, and at PHOUSE1 from June 17, 2021 through July 21, 2021 because spill prevented access resulting in battery loss. BYPASS2 was not deployed until August 2, 2021.

**Figure 5.2-2. Time series of temperatures at Gorge bypass reach (BYPASS1-3) and Powerhouse (PHOUSE1) sites (January 28-October 5, 2021).**

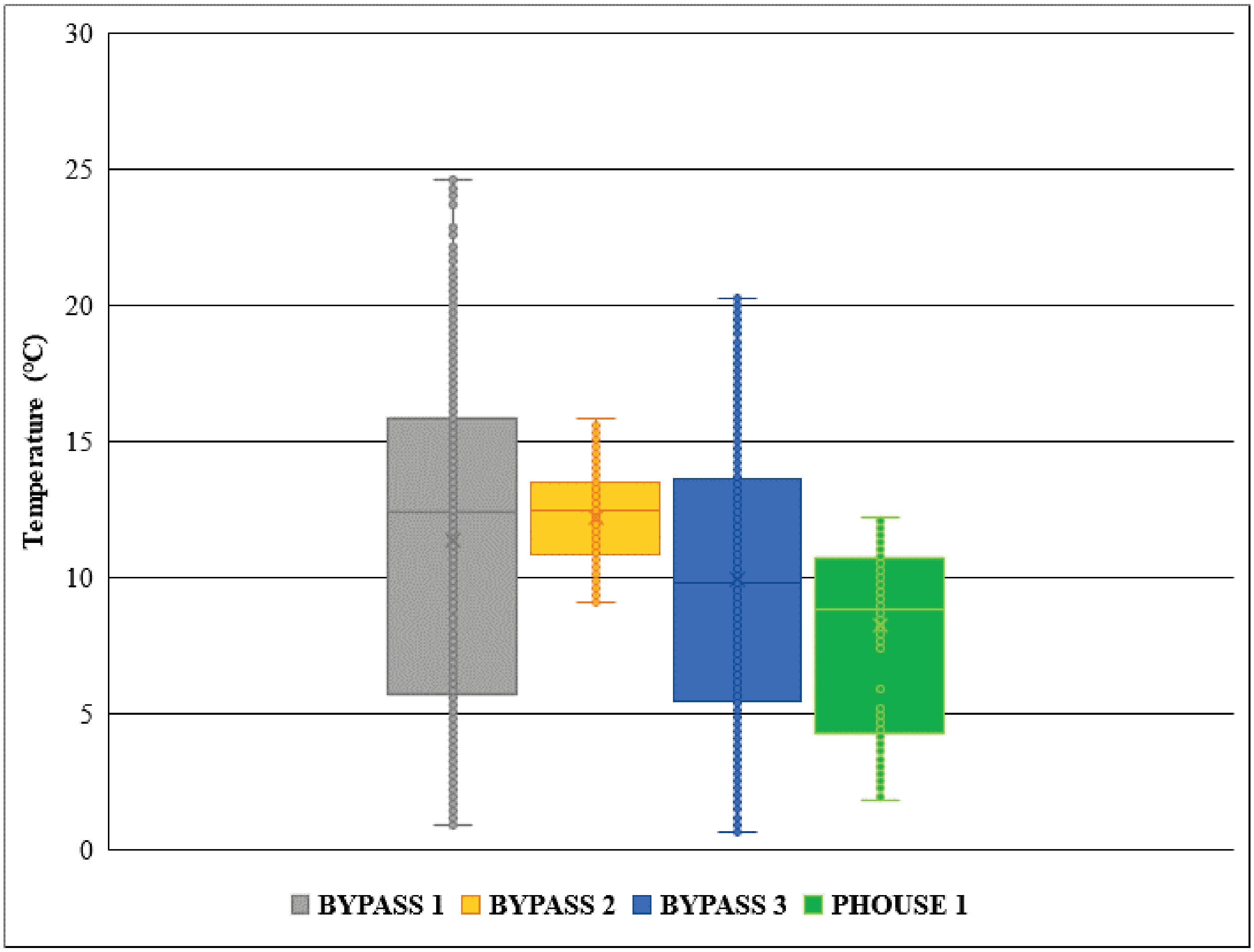



**Figure 5.2-3.** **Box-and-whisker plot showing temperature at the Gorge bypass reach (BYPASS1-3) and Powerhouse (PHOUSE1) sites (January 28-October 5, 2021).**

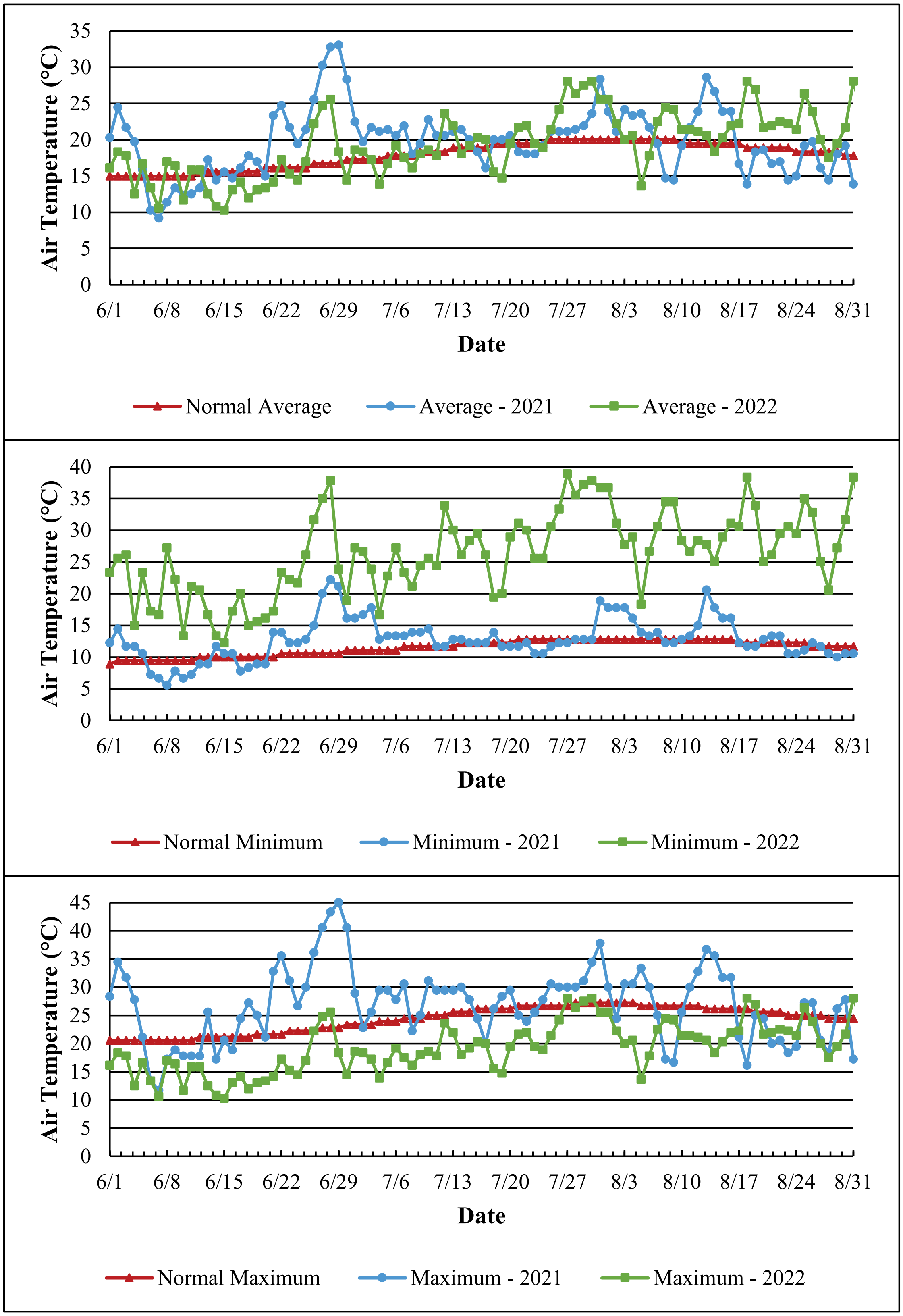
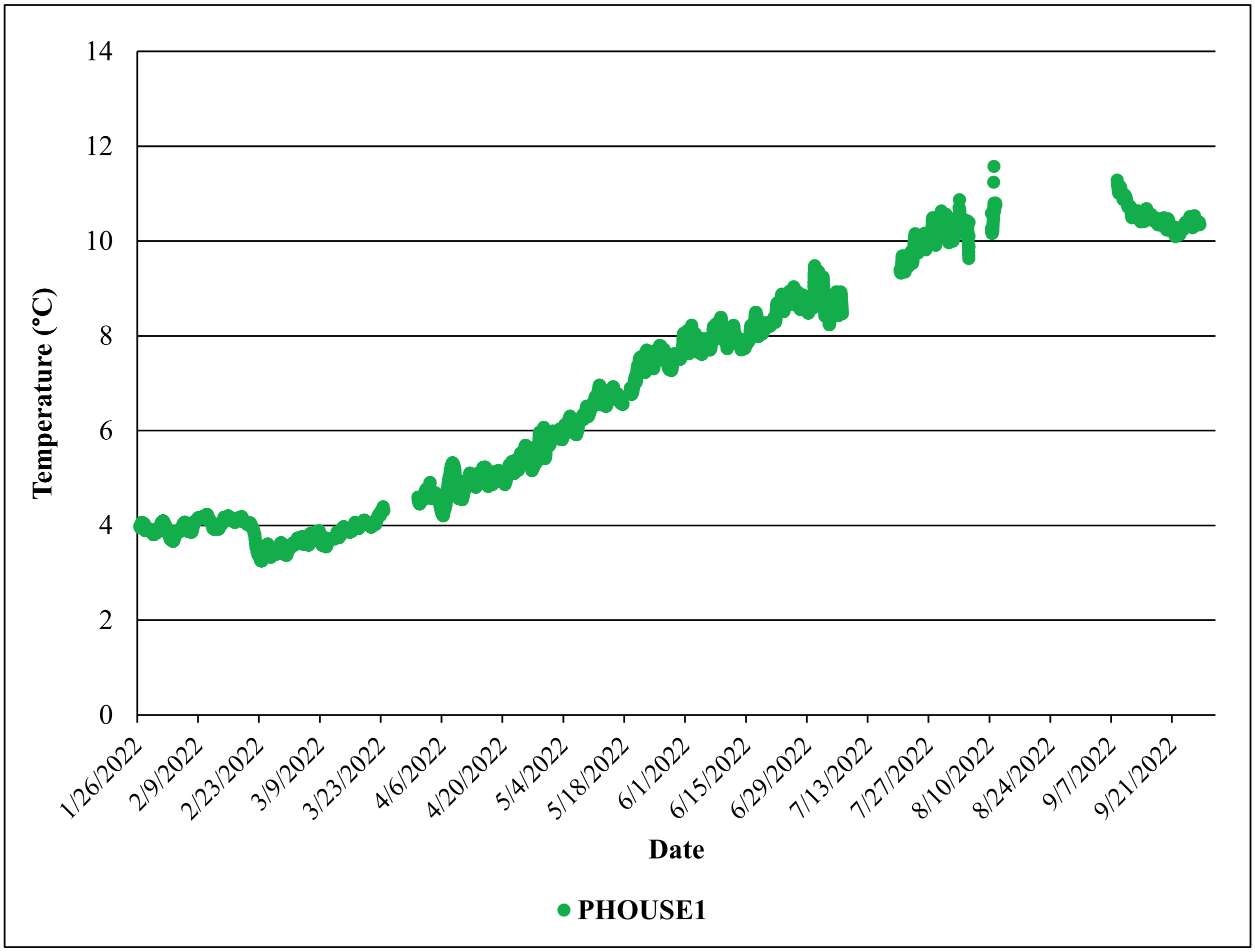



**Figure 5.2-4. Normal, 2021, and 2022 air temperatures (daily average, minimum, and maximum) at Newhalem, Washington, (June, July, and August). Source: NWS 2022.**

Water temperature at PHOUSE1 in 2022 ranged from a minimum of 3.3°C in February, to a high of 11.6°C in August (Figure 5.2-5). Short gaps in data collection occurred due to instrument failure, battery loss, or limited access due to high flows.




Note: Sample data not available at PHOUSE1 from March 23, 2022 to March 31, 2022 because the unit was dewatered, from July 7, 2022 to July 20, 2022 because spill prevented access resulting in battery loss, and from August 11, 2022 through September 8, 2022 due to equipment failure.

**Figure 5.2-5. Time series of temperature at Gorge Powerhouse (PHOUSE1) (January 26-September 27, 2022).**

Short-term deployments occurred at BYPASS3 in June, July, September, and October, and in September and October at BYPASS1. At BYPASS3, temperatures ranged from around 10°C in June to around 17°C in September. At BYPASS1 temperatures reached 20°C in September (Figure 5.2-6).

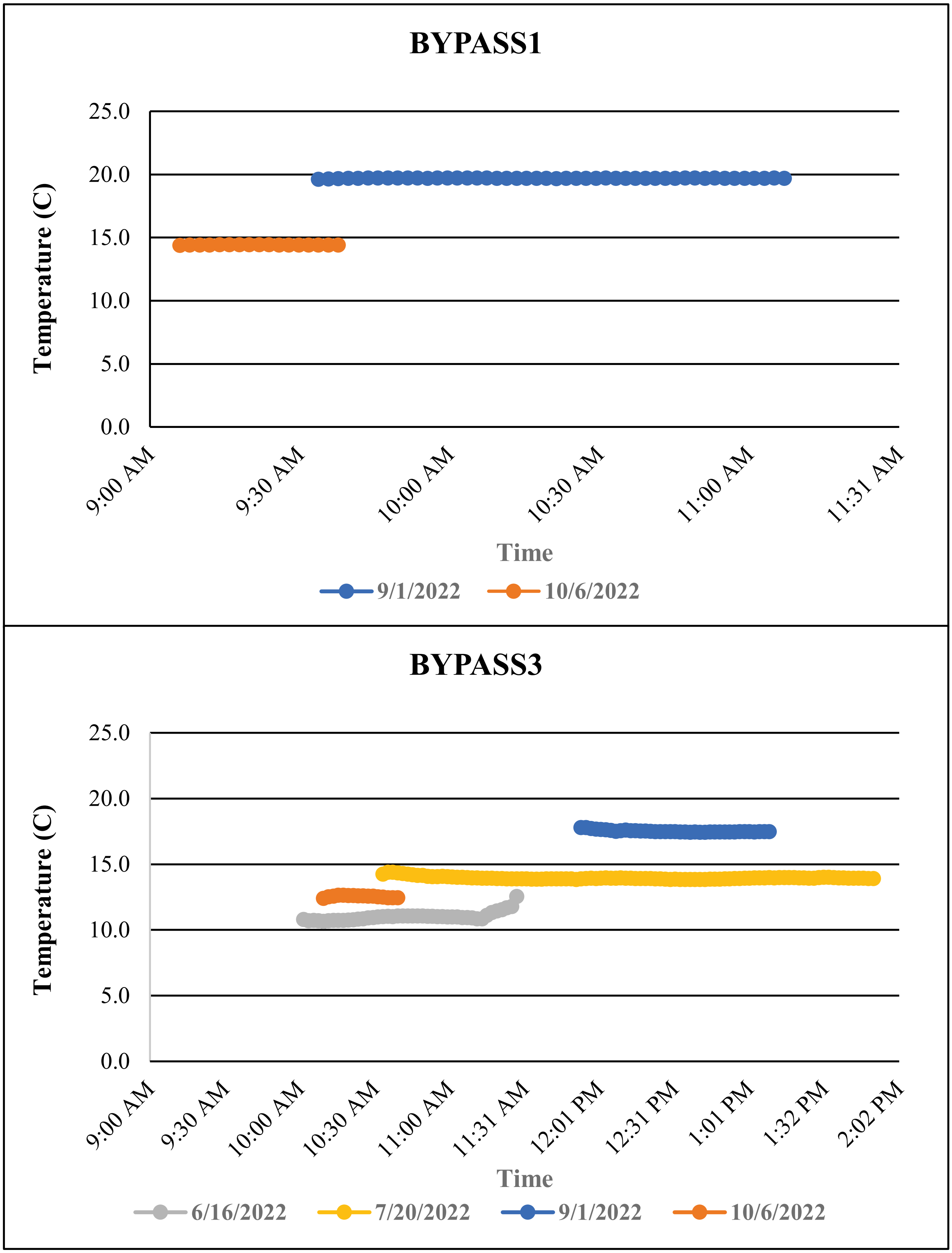
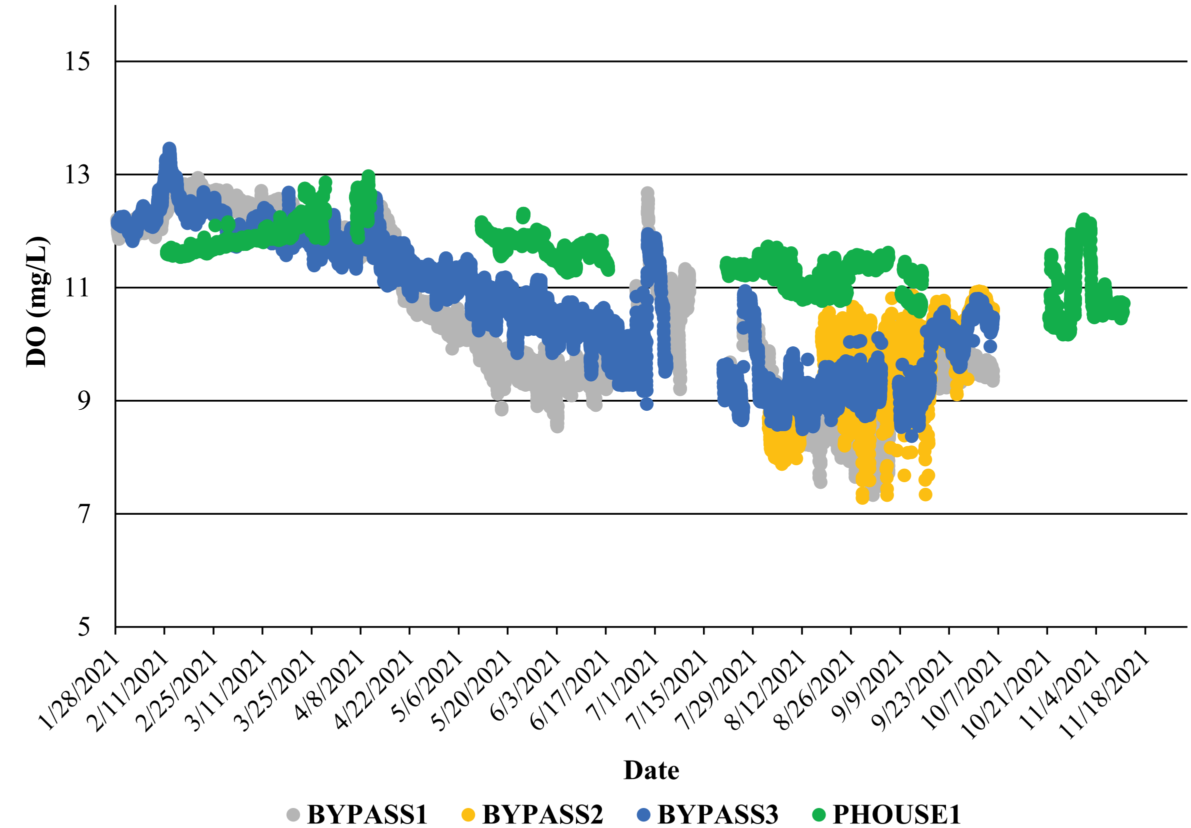



**Figure 5.2-6. Short-term deployment time series of temperature at Gorge bypass reach sites (BYPASS1 and 3) (June-October 2022).**

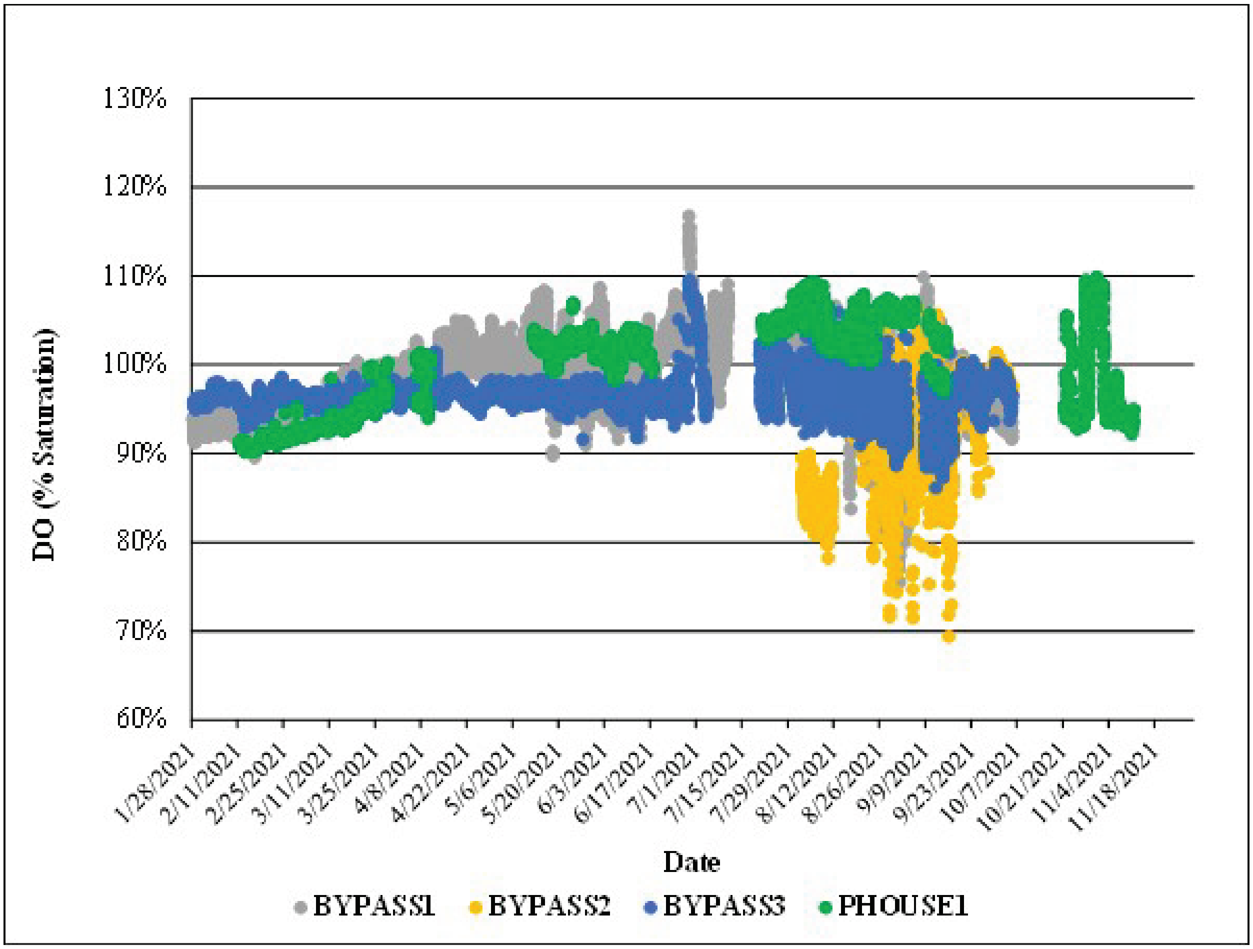
### 5.2.2 Dissolved Oxygen

Time series and box-and-whisker plots of DO in 2021 are shown below in Figures 5.2-7 through 5.2-10. DO concentrations at BYPASS1 and BYPASS2 sites gradually decreased throughout the 2021 monitoring period as temperatures increased. DO at PHOUSE1 in 2021 was generally higher (and water temperatures were lower), and concentrations demonstrated comparatively little diel variability; in contrast to BYPASS2 data are more variable. In 2021, 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 in 2021 was 7.3 mg/L at both BYPASS1 and BYPASS2, 8.4 mg/L at BYPASS3, and 10.6 mg/L at PHOUSE1.




Note: Sample data not available at PHOUSE1 from April 10, 2021 to May 12, 2021 because the unit was dewatered. Sample data not available at BYPASS1 from July 10, 2021 through July 22, 2021, at BYPASS3 from July 4, 2021 through July 20, 2021, and at PHOUSE1 from June 17, 2021 through July 21, 2021 because spill prevented access resulting in battery loss. BYPASS2 was not deployed until August 2, 2021. Sample data not available at PHOUSE1 from September 22, 2021 to October 21, 2021 due to equipment issues. Sample data not available after October 19, 2021 at BYPASS1-2, October 5, 2021 at BYPASS3, and November 17, 2021 at PHOUSE1 because weather conditions followed by spill prevented access resulting in equipment loss or damage.

**Figure 5.2-7. Time series of DO concentration at the Gorge bypass reach (BYPASS1-3) and Gorge Powerhouse (PHOUSE1) sites (January 28-November 11, 2021).**




Note: Sample data not available at PHOUSE1 from April 10, 2021 to May 12, 2021 because the unit was dewatered. Sample data not available at BYPASS1 from July 10, 2021 through July 22, 2021, at BYPASS3 from July 4, 2021 through July 20, 2021, and at PHOUSE1 from June 17, 2021 through July 21, 2021 because spill prevented access resulting in battery loss. BYPASS2 was not deployed until August 2, 2021. Sample data not available at PHOUSE1 from September 22, 2021 to October 21, 2021 due to equipment issues. Sample data not available after October 19, 2021 at BYPASS1-2, October 5, 2021 at BYPASS3, and November 17, 2021 at PHOUSE1 because weather conditions followed by spill prevented access resulting in equipment loss or damage.

**Figure 5.2-8. Time series of DO saturation at the Gorge bypass reach (BYPASS1-3) and Gorge Powerhouse (PHOUSE1) sites (January 28-November 11, 2021).**

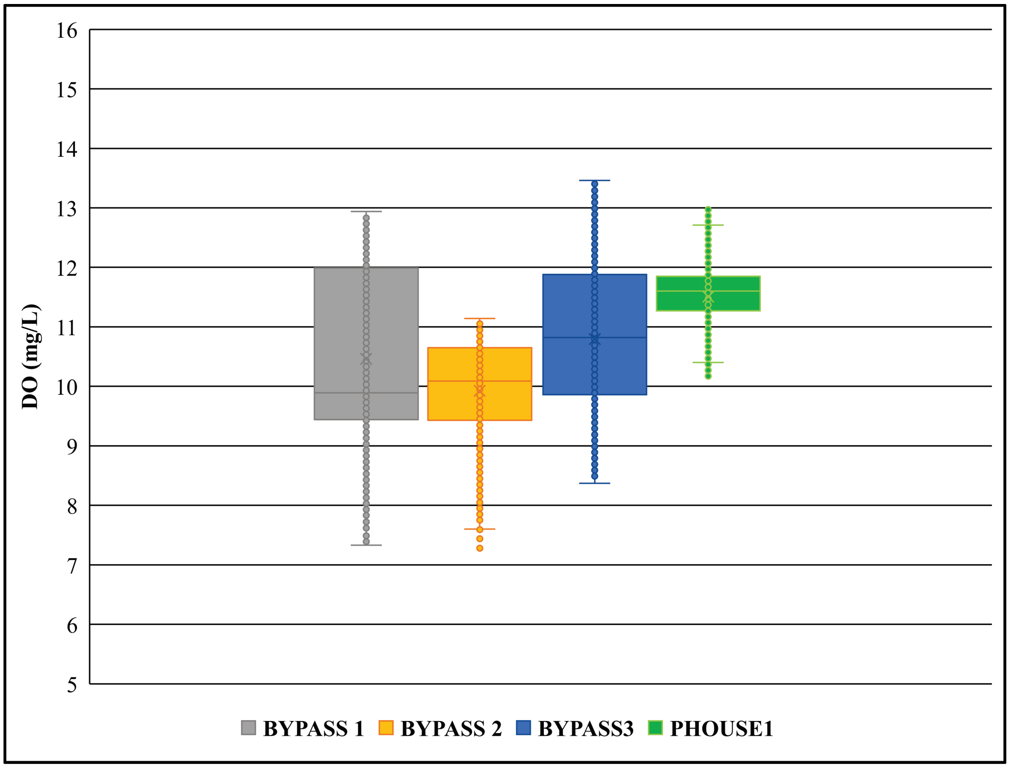



**Figure 5.2-9.** **Box-and-whisker plot of DO concentration at the Gorge bypass reach (BYPASS1-3) and Powerhouse (PHOUSE1) sites (January 28-October 5, 2021).**

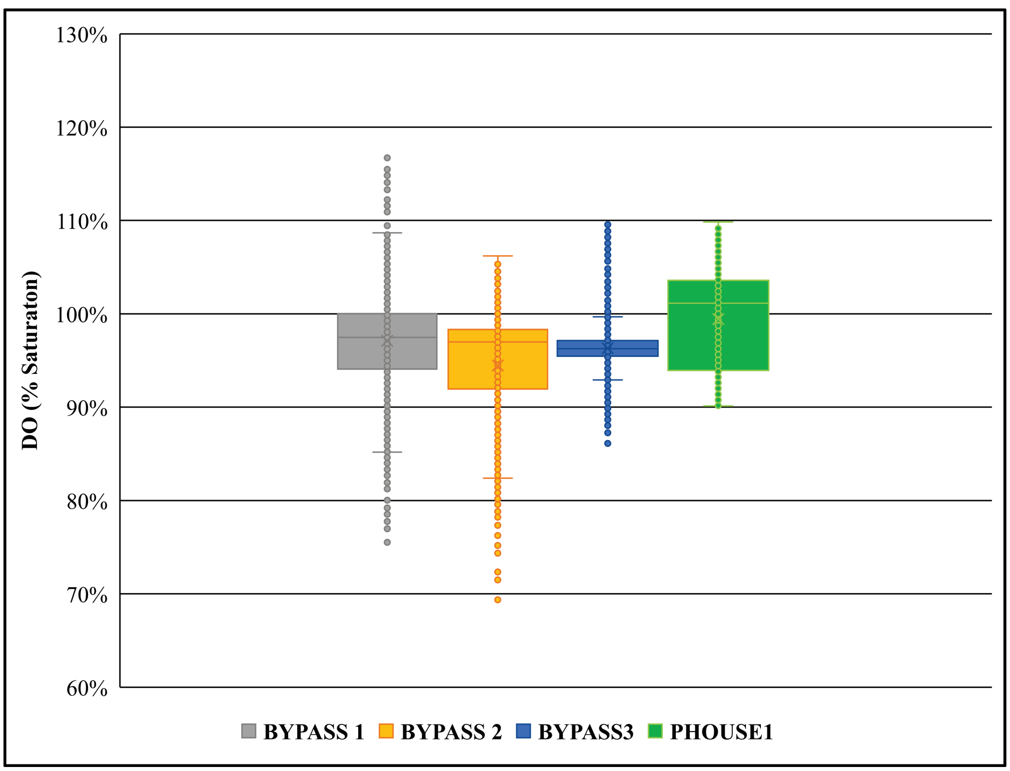
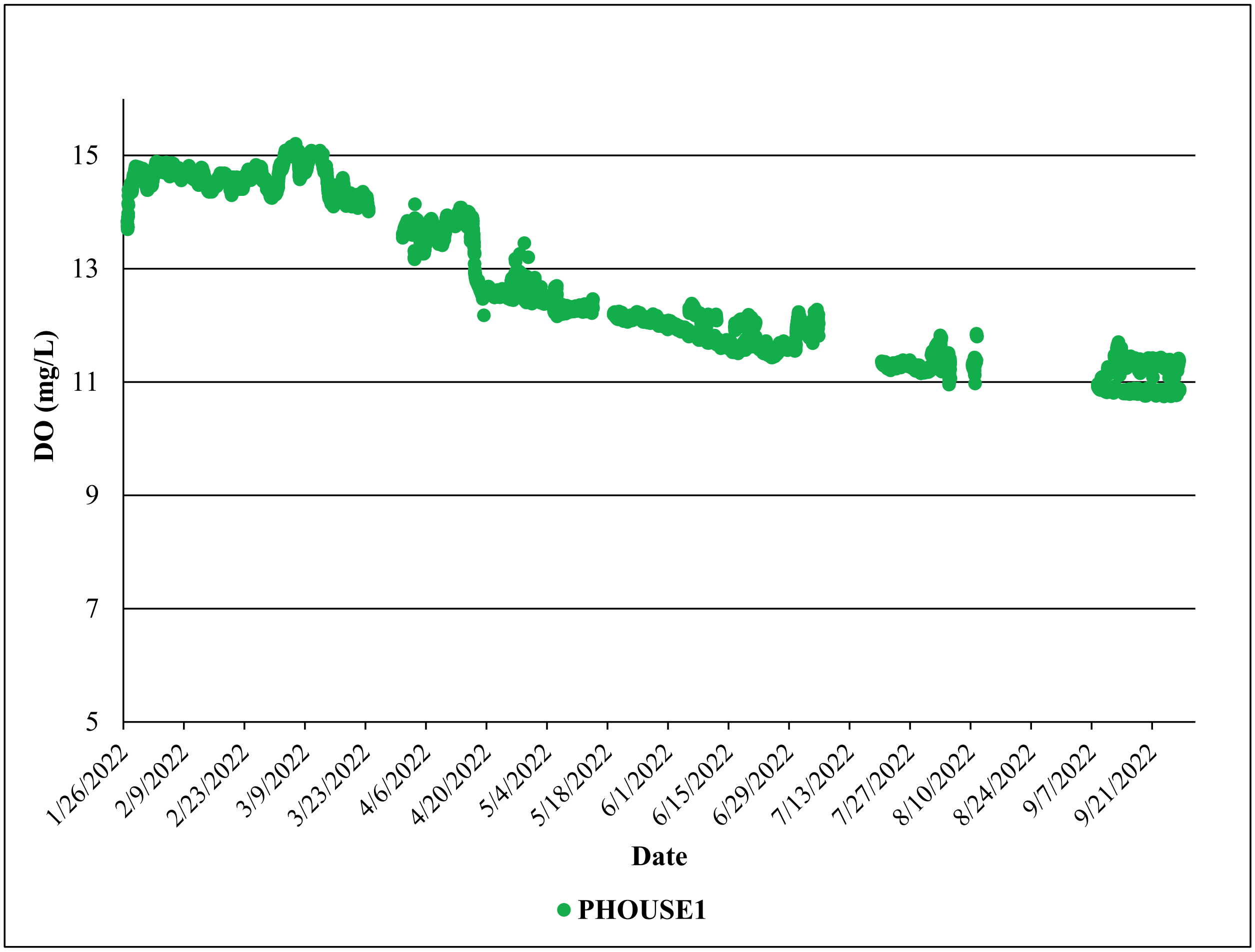


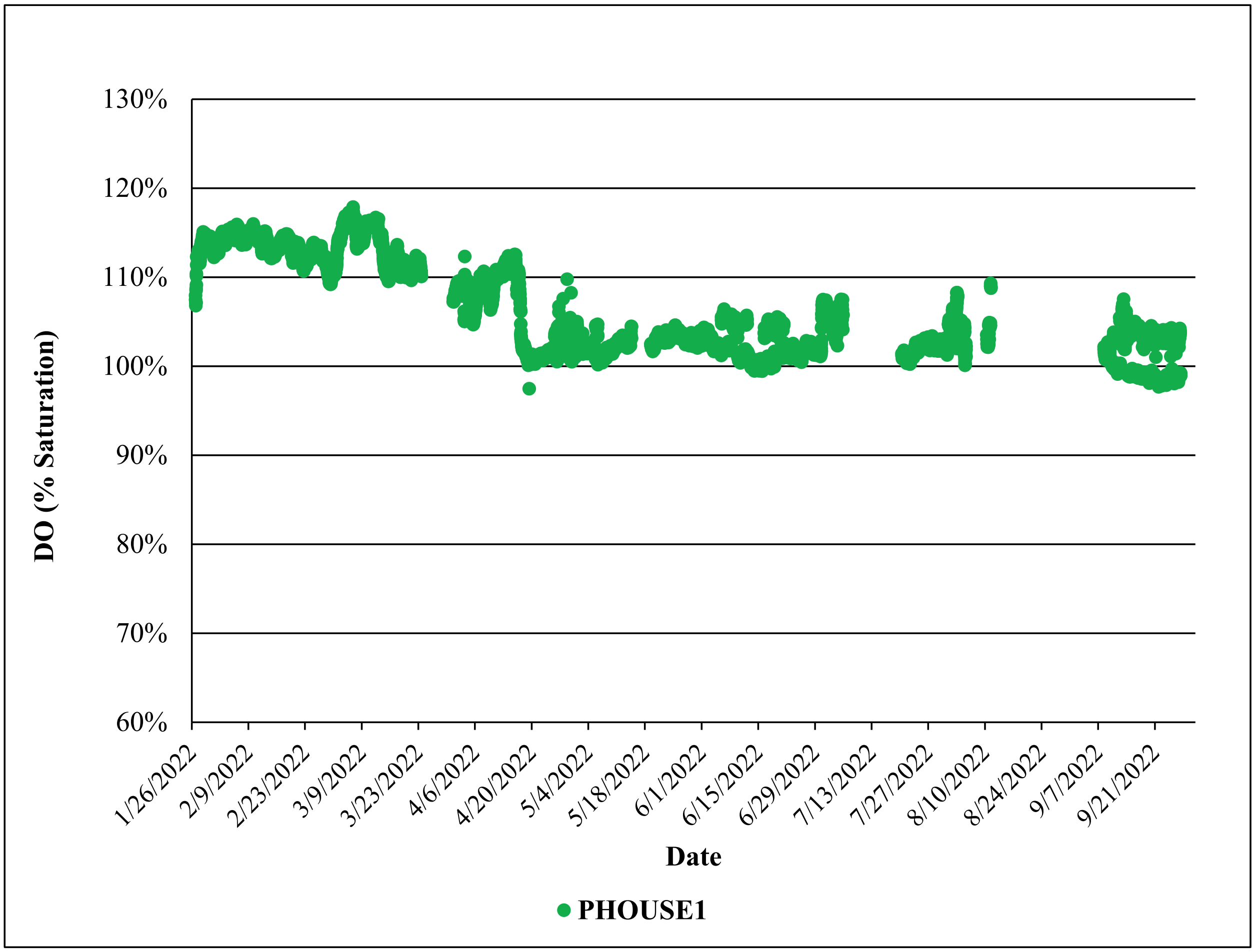

**Figure 5.2-10.** **Box-and-whisker plot of DO saturation at the Gorge bypass reach (BYPASS1-3) and Powerhouse (PHOUSE1) sites (January 28-October 5, 2021).**

DO at PHOUSE1 in 2022 ranged from a high of over 15.0 mg/L (118 percent saturation) in March, to a low of 10.7 mg/L (98 percent saturation) in September (Figures 5.2-11 and 5.2-12). Short gaps in data collection occurred due to instrument failure, battery loss, or limited access due to high flows.




Note: Sample data not available at PHOUSE1 from March 23, 2022 to March 31, 2022 because the unit was dewatered, from July 7, 2022 to July 20, 2022 because spill prevented access resulting in battery loss, and from August 11, 2022 through September 8, 2022 due to equipment failure.

**Figure 5.2-11. Time series of DO concentration at Gorge Powerhouse (PHOUSE1) (January 26-September 27, 2022).**




Note: Sample data not available at PHOUSE1 from March 23, 2022 to March 31, 2022 because the unit was dewatered, from July 7, 2022 to July 20, 2022 because spill prevented access resulting in battery loss, and from August 11, 2022 through September 8, 2022 due to equipment failure.

**Figure 5.2-12. Time series of DO saturation at Gorge Powerhouse (PHOUSE1) (January 26-September 27, 2022).**

Short-term deployments occurred at BYPASS3 in June, July, September, and October, and in September and October at BYPASS1. DO ranged from around 11.5 mg/L (105 percent saturation) in June at BYPASS3 to around 8.0 mg/L (87 percent saturation) at BYPASS3 in September and 9.8 mg/L (98 percent saturation) at BYPASS1 in September (Figure 5.2-13 and 5.2-14).

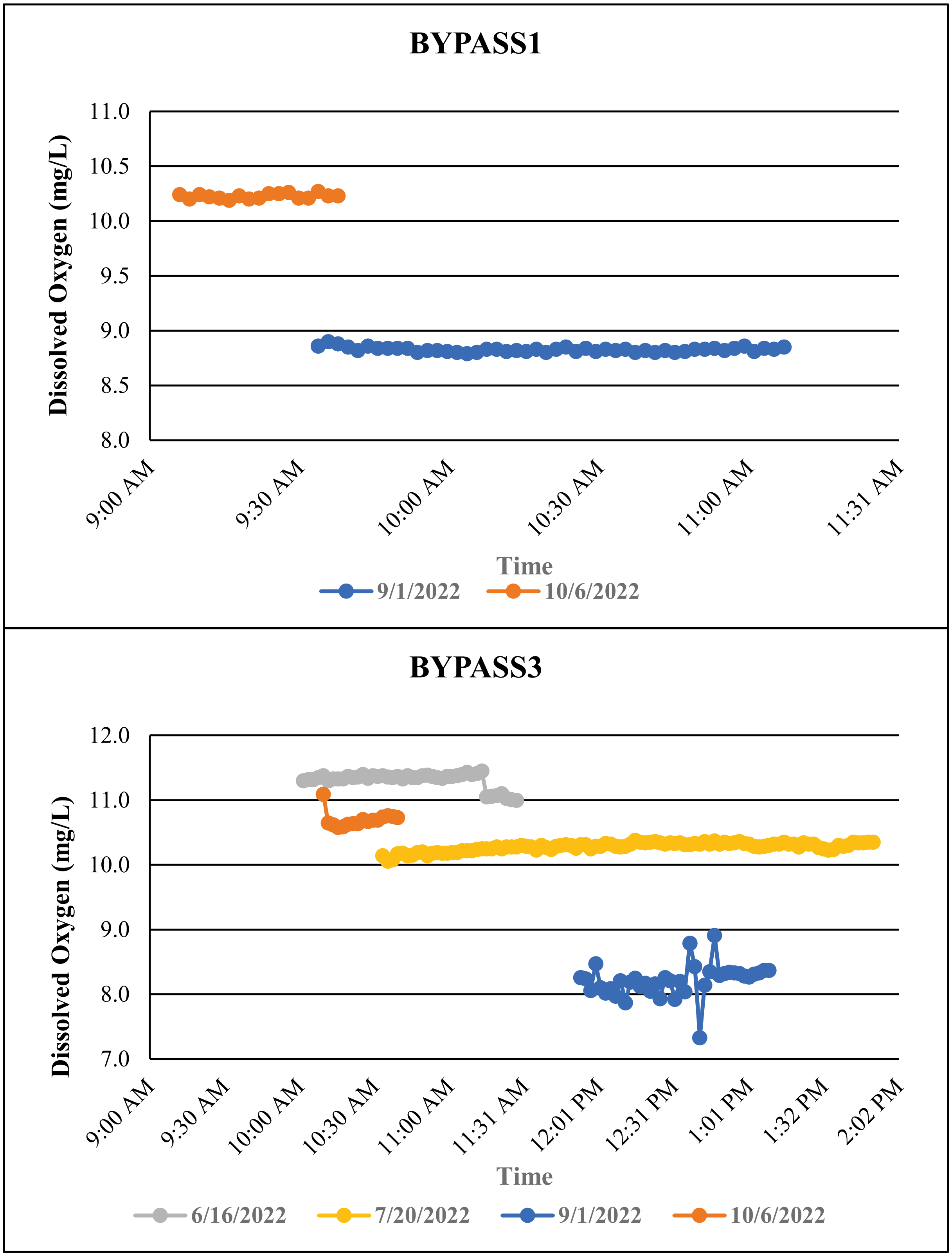



**Figure 5.2-13.** **Short-term deployment time series of DO concentration at Gorge bypass reach sites (BYPASS1 and 3) (June-October 2022).**

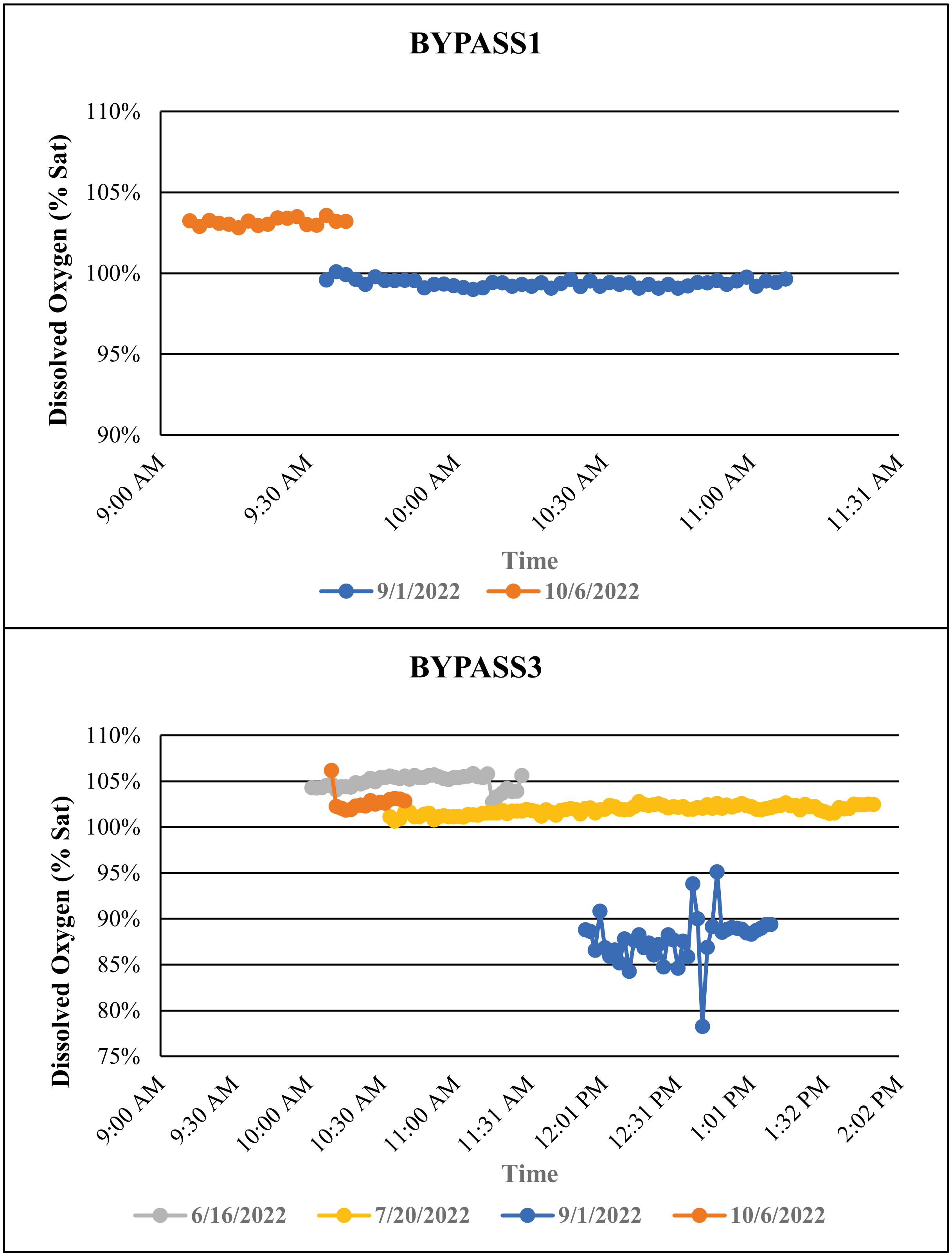
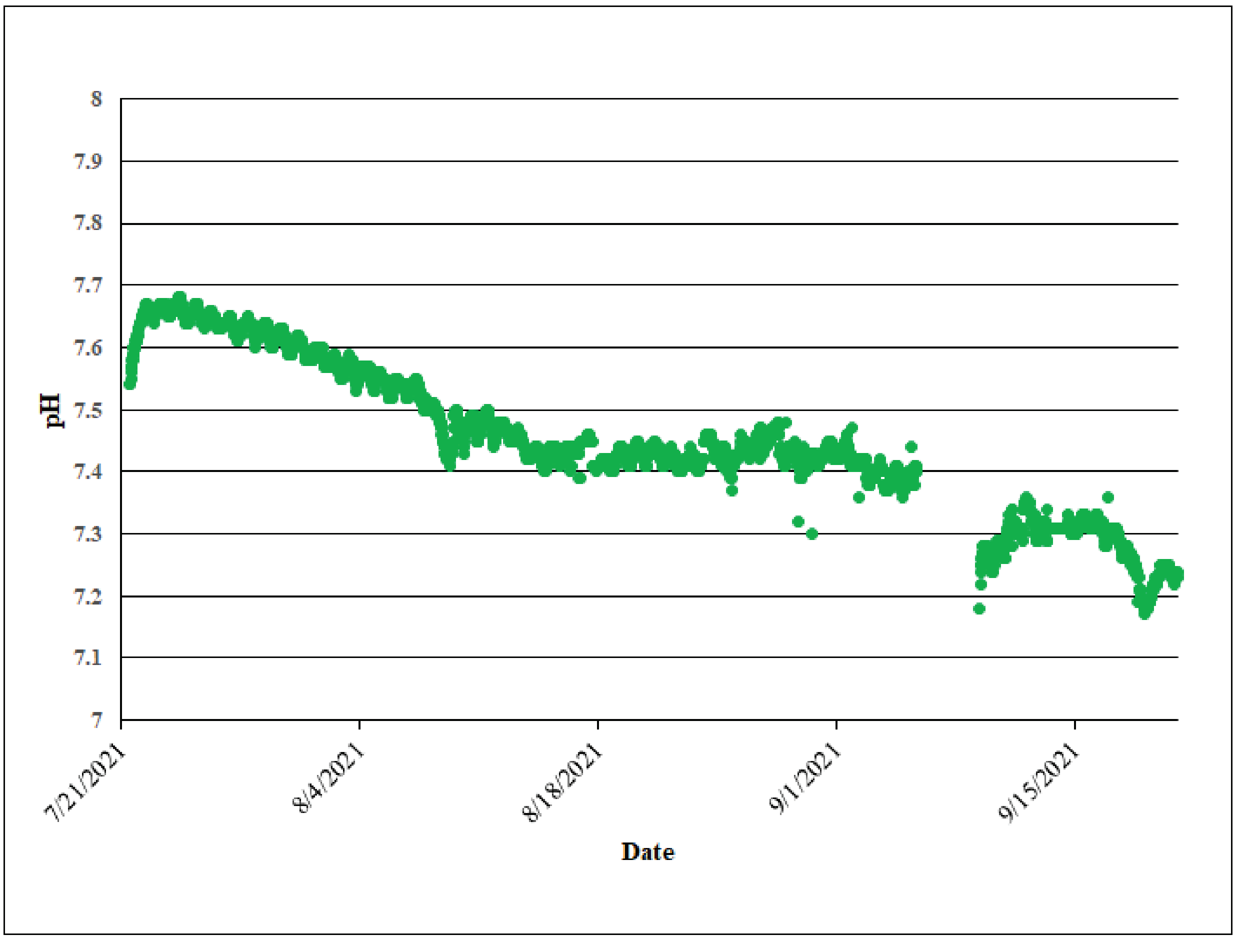



**Figure 5.2-14. Short-term deployment time series of DO saturation at Gorge bypass reach sites (BYPASS1 and 3) (June-October 2022).**

### 5.2.3 pH

Per the RSP, pH is monitored at PHOUSE1 only. As noted in Section 4.1, data were collected at this site prior to the RSP study period. When data collection began in January 2021, a sonde 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.

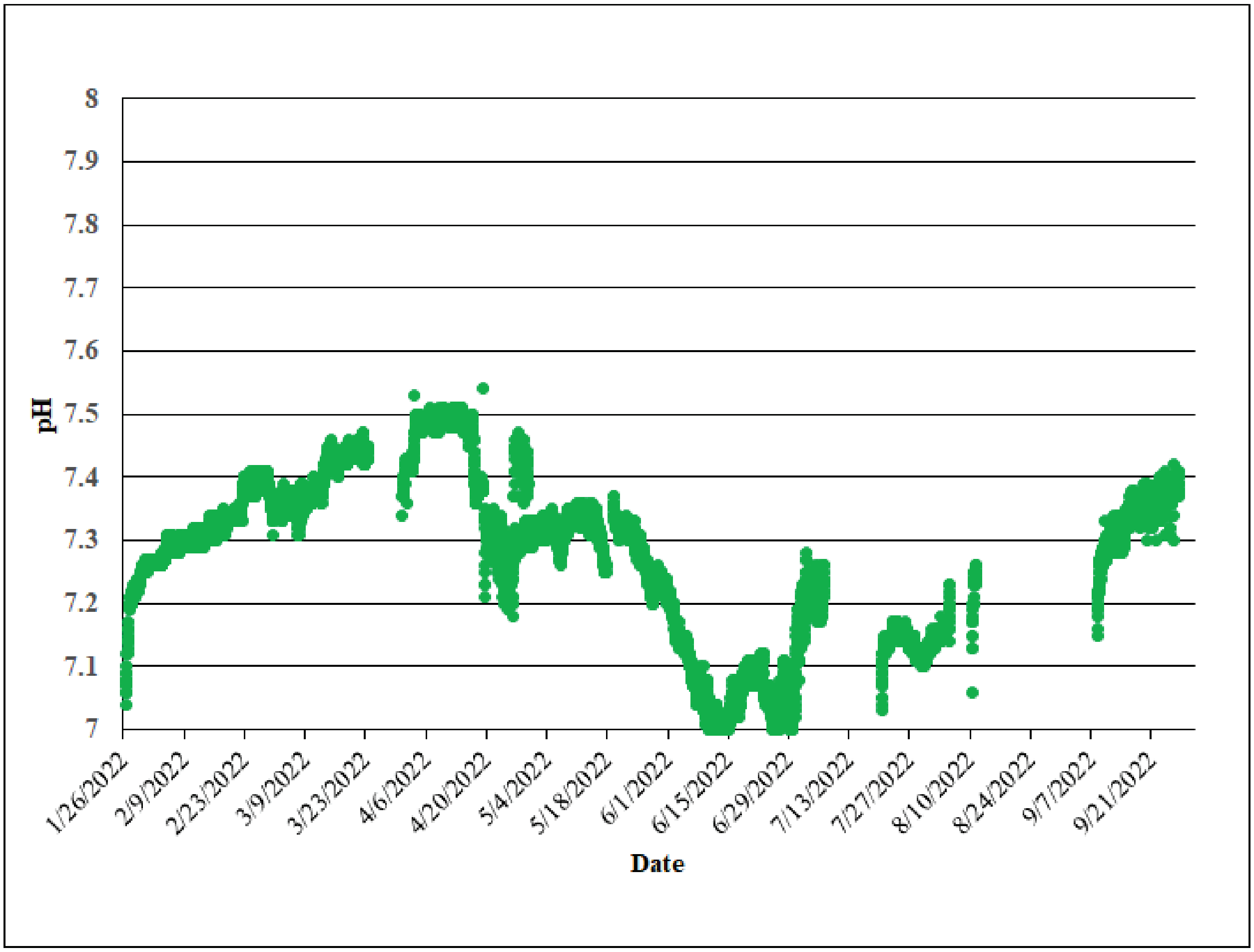
In 2021, pH values averaged 7.5 with a range of 7.2 to 7.7 (Figure 5.2-15). However, all pH data were qualified based on exceedance of performance check thresholds (within 0.3 pH units) over three successive visits (August, September, and October). Discussion with the manufacturer (Hach) suggests that performance of the pH probe and decreasing values may have been due to leakage of the potassium chloride reference solution in the pH probe caused by continued exposure to high velocity water. The pH sensor was recalibrated when performance check thresholds were exceeded, and the reference solution was replaced when the sensor did not pass two successive performance checks. The data collected prior to each performance check was evaluated and determined to be within a reasonable deviation, and was therefore considered qualified, rather than rejected outright.




Note: Sample data not available at PHOUSE1 from September 5, 2021 to September 9, 2021 due to battery loss.

**Figure 5.2-15. Time series of pH at Gorge Powerhouse (PHOUSE1) (July 22-October 5, 2021).**

At PHOUSE1 in 2022 pH ranged from about 7.0 to 7.6 (Figure 5.2-16). Short gaps in data collection occurred due to instrument failure, battery loss, or limited access due to high flows. As in 2021, many of the pH values are considered qualified (39 percent) due to exceedance of performance check thresholds, despite regular recalibration of the pH sensor and replacement of reference solution. Data was evaluated and is considered qualified, rather than rejected.



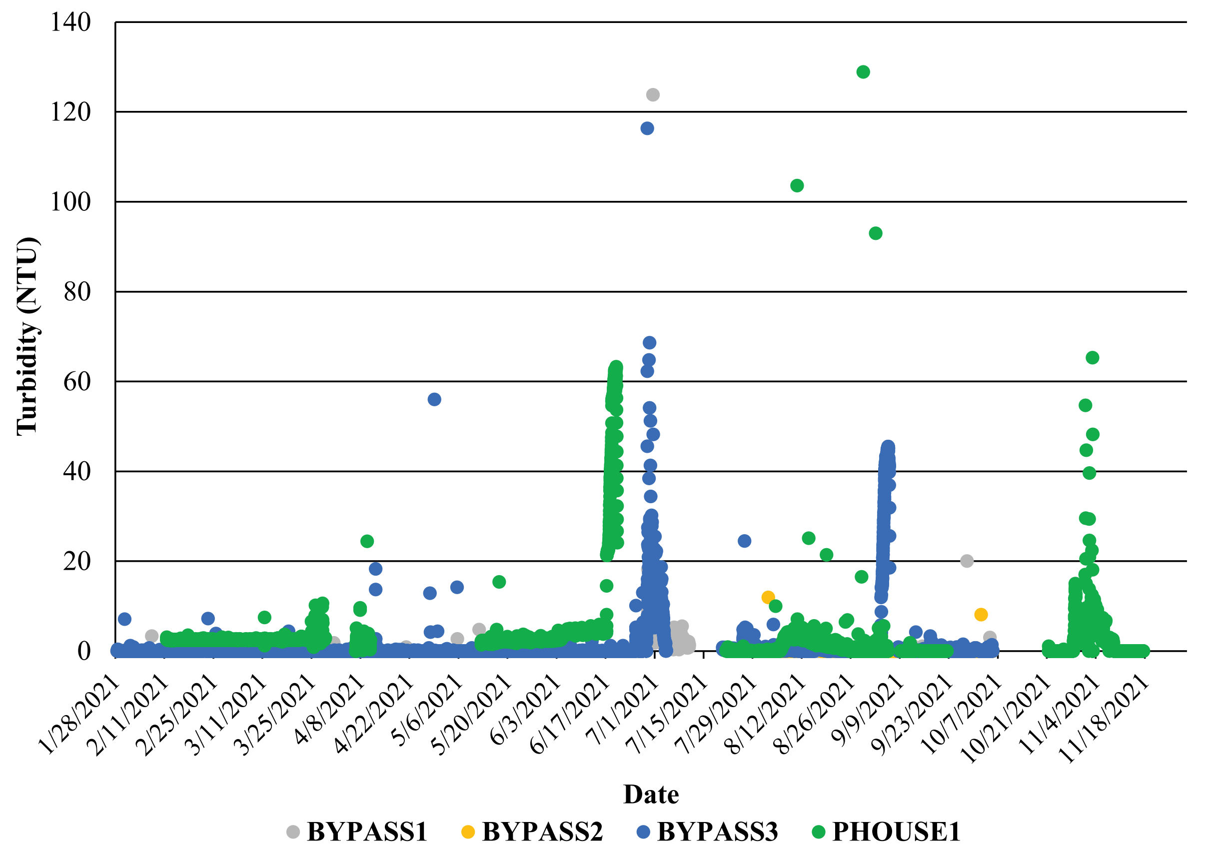

Note: Sample data not available at PHOUSE1 from March 23, 2022 to March 31, 2022 because the unit was dewatered, from July 7, 2022 to July 20, 2022 because spill prevented access resulting in battery loss, and from August 11, 2022 through September 8, 2022 due to equipment failure.

**Figure 5.2-16. Time series of pH at Gorge Powerhouse (PHOUSE1) (January 26-September 27, 2022).**

### 5.2.4 Turbidity and Total Suspended Solids

Turbidity was generally very low at all monitoring sites in the Gorge bypass reach and below Gorge Powerhouse in 2021, averaging near or less than 1 NTU (Figure 5.2-17). Turbidity at BYPASS3 during late June 2021 increased to nearly 120 NTUs, 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, 2021, and 93 NTUs on September 2, 2021). However, these were isolated "spike" values among otherwise low turbidity (near 1 NTU), and there was no spill at Gorge Dam during this time. Review of data at the USGS

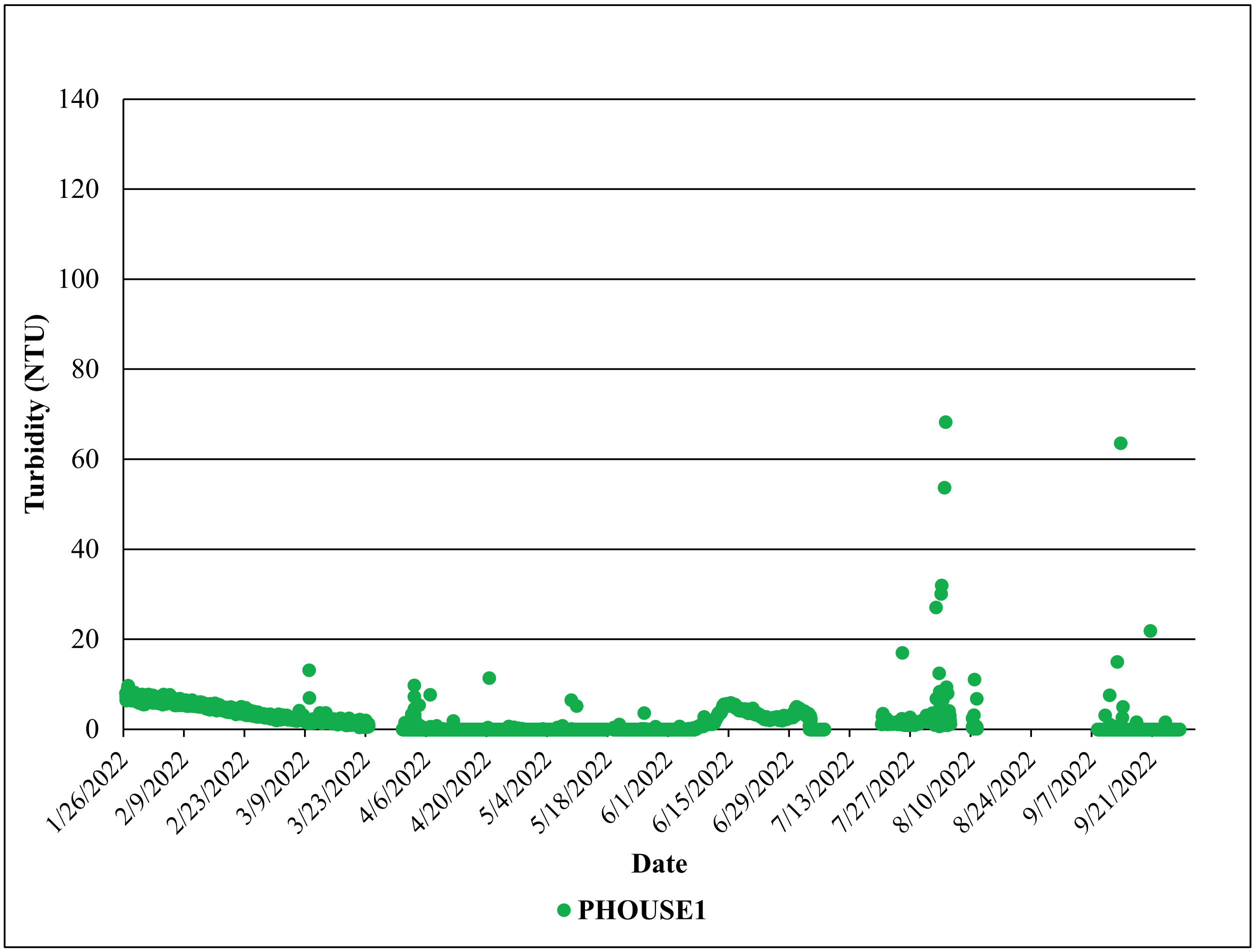
Newhalem gage (12178000) indicates flows were relatively stable during this period, suggesting that debris was interfering with the sonde's optical sensor. Similarly, with respect to BYPASS3, flows at Newhalem were level at approximately 2,200 cfs during the first week of September 2021, and review of NWS climate data indicates that there was no precipitation at this time that could have led to elevated turbidity, e.g., hillslope runoff (NWS 2022). Increased turbidity at BYPASS3 may also be a result of debris or possibly algal growth on the turbidity sensor.




Note: Sample data not available at PHOUSE1 from April 10, 2021 to May 12, 2021 because the unit was dewatered. Sample data not available at BYPASS1 from July 10, 2021 through July 22, 2021 at BYPASS3 from July 4, 2021 through July 20, 2021, and at PHOUSE1 from June 17, 2021 through July 21, 2021 because spill prevented access resulting in battery loss. BYPASS2 was not deployed until August 2, 2021. Sample data not available at PHOUSE1 from September 22, 2021 to October 21, 2021 due to equipment issues. Sample data not available after October 19, 2021 at BYPASS1-2, October 5, 2021 at BYPASS3, and November 17, 2021 at PHOUSE1 because weather conditions followed by spill prevented access resulting in equipment loss or damage.

**Figure 5.2-17. Turbidity at the Gorge bypass reach (BYPASS1-3) and Powerhouse (PHOUSE1) sites (January 28-November 11, 2021).**

Turbidity at PHOUSE1 in 2022 was typically less than 5 NTUs, with occasional elevated measurements less than 12 NTUs. There were two events when turbidity was elevated in 2022 in early August and mid-September. Both events were less than 70 NTUs (Figure 5.2-18). Short gaps in data collection occurred due to instrument failure, battery loss, or limited access due to high flows.




Note: Sample data not available at PHOUSE1 from March 23, 2022 to March 31, 2022 because the unit was dewatered, from July 7, 2022 to July 20, 2022 because spill prevented access resulting in battery loss, and from August 11, 2022 through September 8, 2022 due to equipment failure.

**Figure 5.2-18. Time series of turbidity at Gorge Powerhouse (PHOUSE1) (January 26-September 27, 2022).**

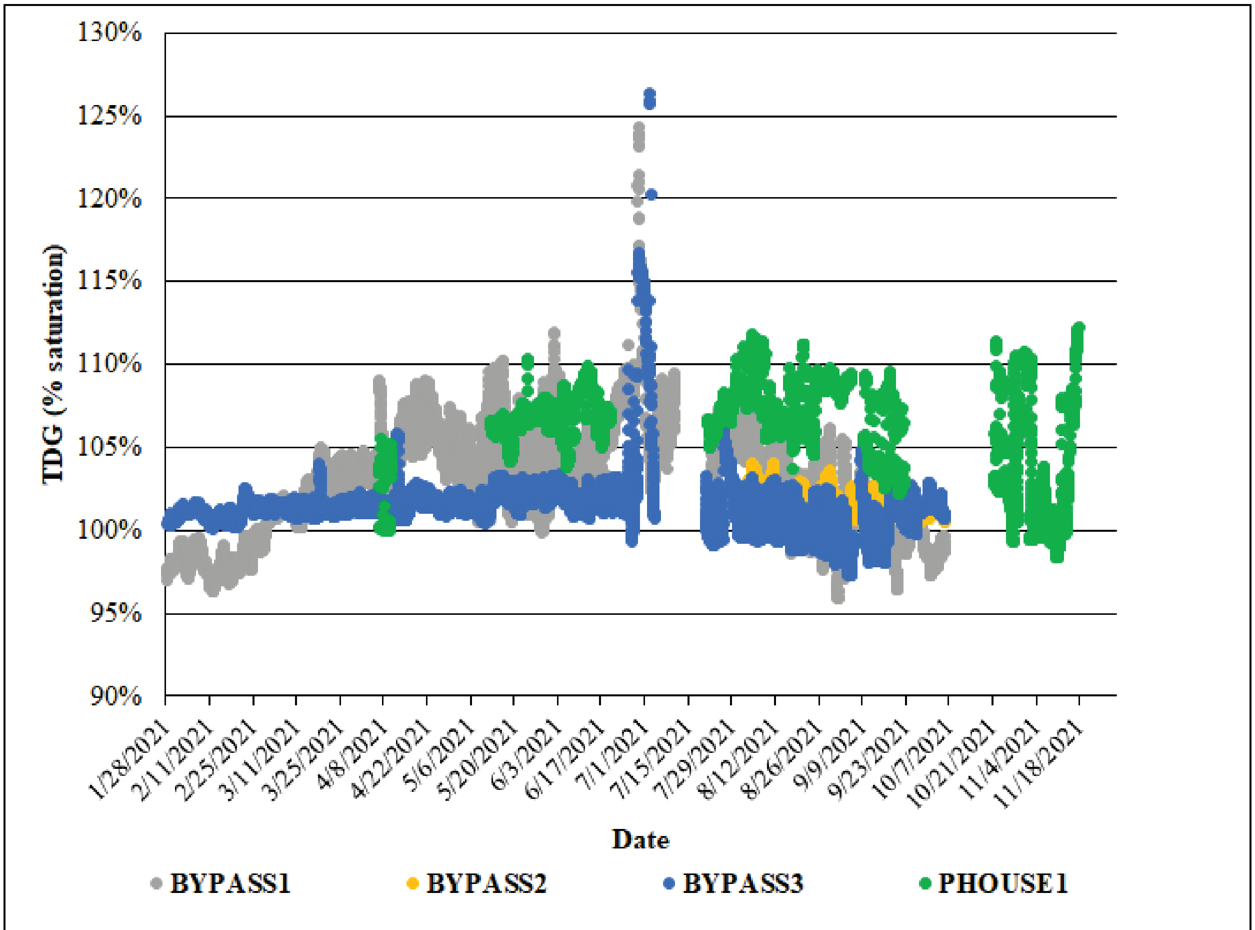
Short-term deployments occurred at BYPASS3 in June, July, September, and October, and in September and October at BYPASS1. Turbidity was undetectable during all short-term deployments with the exception of one measurement of 0.3 NTU at BYPASS3 in September.

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. A second baseline TSS sample was taken at the Powerhouse in early November 2022. Future TSS samples at PHOUSE2 will be collected when turbidity is elevated or during spill events at Gorge Dam.

### 5.2.5 Total Dissolved Gas

#### 5.2.5.1 Continuous Monitoring

Time series and box plots of TDG data collected continuously at the three Gorge bypass reach sites and Gorge Powerhouse in 2021 are shown in Figures 5.2-19 and 5.2-20. Median values for all sites in 2021 were between 101 percent and 103 percent saturation. In 2021, maximum percent saturation at BYPASS1 in the Gorge plunge pool was 124 percent during a spill event in late June. Values were also elevated during this same event at BYPASS3, although data at BYPASS3 are qualified over this period based on the mid-deployment check conducted on July 20 (see Section 5.2.8). 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 at various times from August to November 2021.




Note: Sample data not available at PHOUSE1 from April 10, 2021 to May 12, 2021 because the unit was dewatered. Sample data not available at BYPASS1 from July 10, 2021 through July 22, 2021, at BYPASS3 from July 4, 2021 through July 20, 2021, and at PHOUSE1 from June 17, 2021 through July 21, 2021 because spill prevented access resulting in battery loss. BYPASS2 was not deployed until August 2, 2021. Sample data not available at PHOUSE1 from September 22, 2021 to October 21, 2021 due to equipment issues. Sample data not available after October 19, 2021 at BYPASS1-2, October 5, 2021 at BYPASS3, and November 17, 2021 at PHOUSE1 because weather conditions followed by spill prevented access resulting in equipment loss or damage.

**Figure 5.2-19. Time series of TDG at the Gorge bypass reach (BYPASS1-3) and Powerhouse (PHOUSE1) sites (January 28-November 11, 2021).**

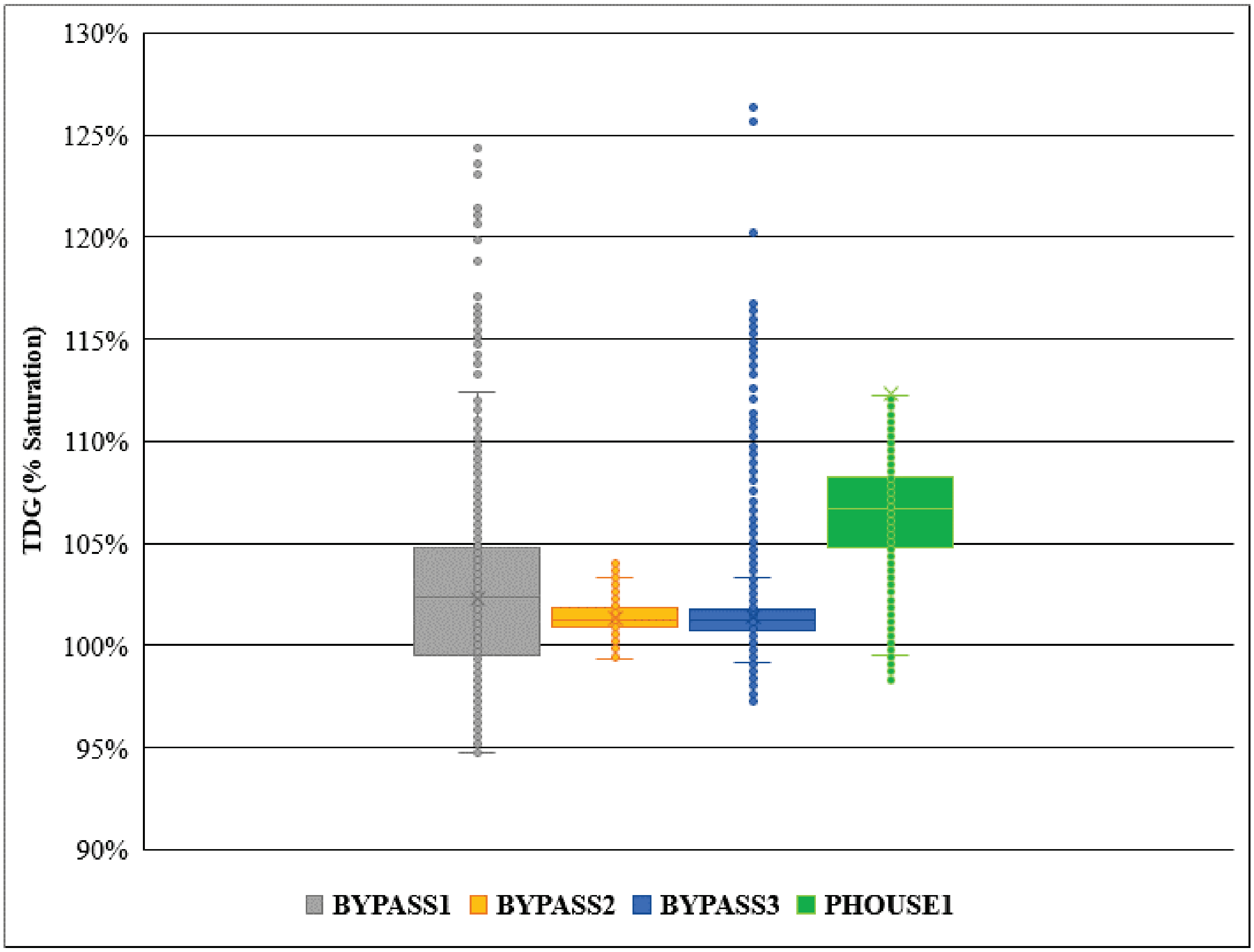



**Figure 5.2-20. Box-and-whisker plots of TDG at the Gorge bypass reach (BYPASS1-3) and Powerhouse (PHOUSE1) sites (2021).**

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, 2021, following record heat. Spills over the last 23 years have primarily occurred from June through August (Figure 5.2-21). City Light flow and spill records indicate that the maximum spill in June/July of 2021 (7,486 cfs on June 29) was approximately four times greater than the median spill event that occurred between 1997 and 2021 (approximately 1,750 cfs, Figure 5.2-22). Two spill events over 20,000 cfs have occurred since 1997: 20,395 cfs on October 22, 2003, and 20,231 cfs on November 17, 2021 (Figure 5.2-23).

TDG data collected during the late June spill event are shown in Figure 5.2-24. Active sites at this time included BYPASS1 and BYPASS3. Data were not collected at Gorge Powerhouse due to external battery failure and safety issues precluding access to the sonde 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 7 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 saturation 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 saturation 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).

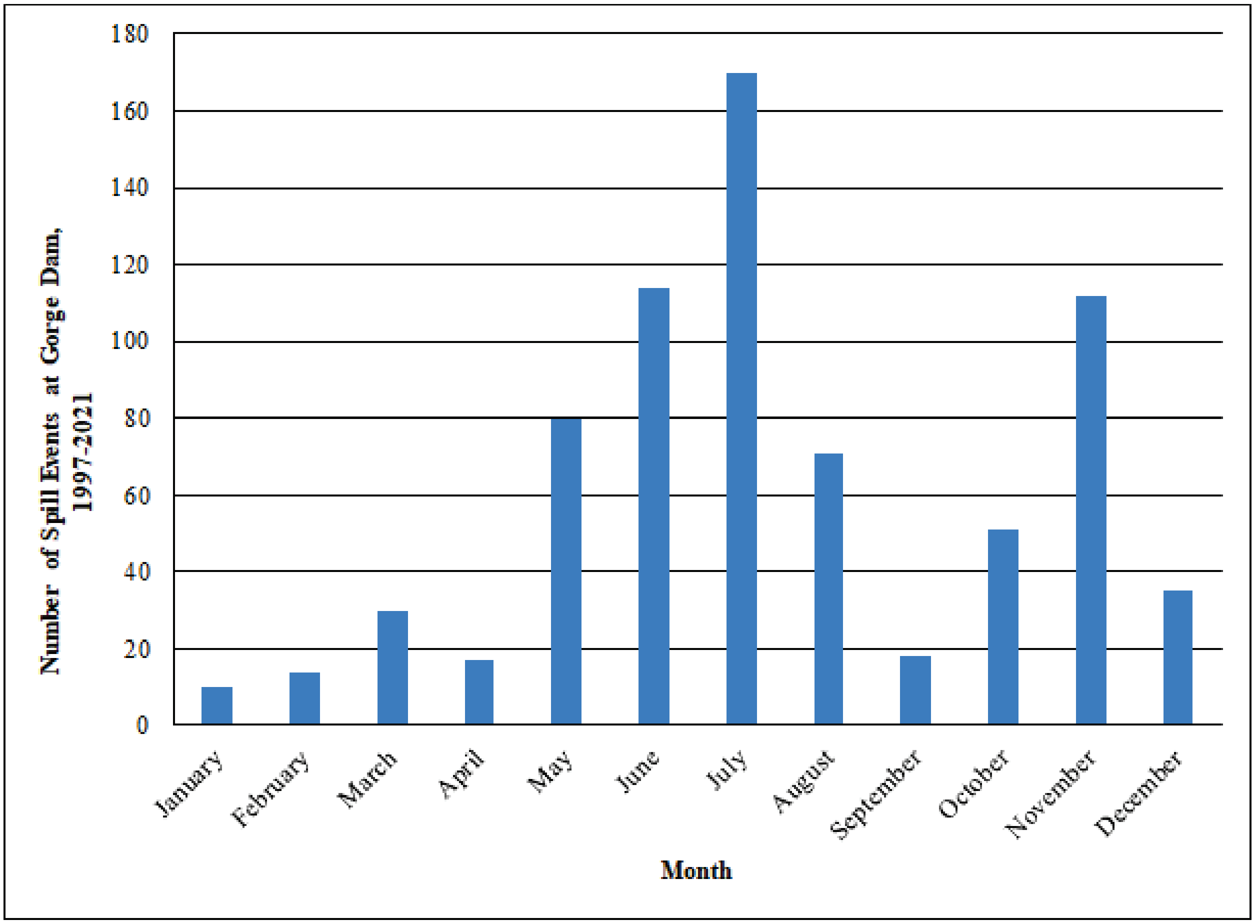



**Figure 5.2-21. Monthly spill events at Gorge Dam (1997-2021).**

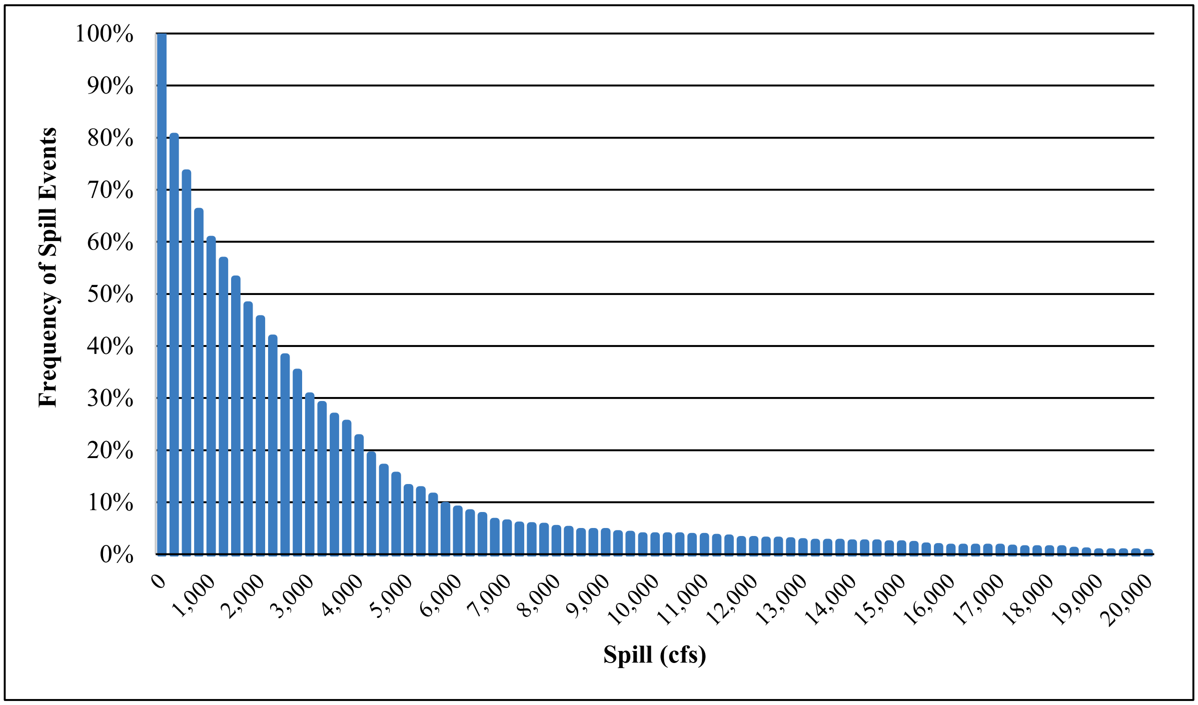



**Figure 5.2-22. Frequency distribution of spill volume at Gorge Dam (1997-2021).**

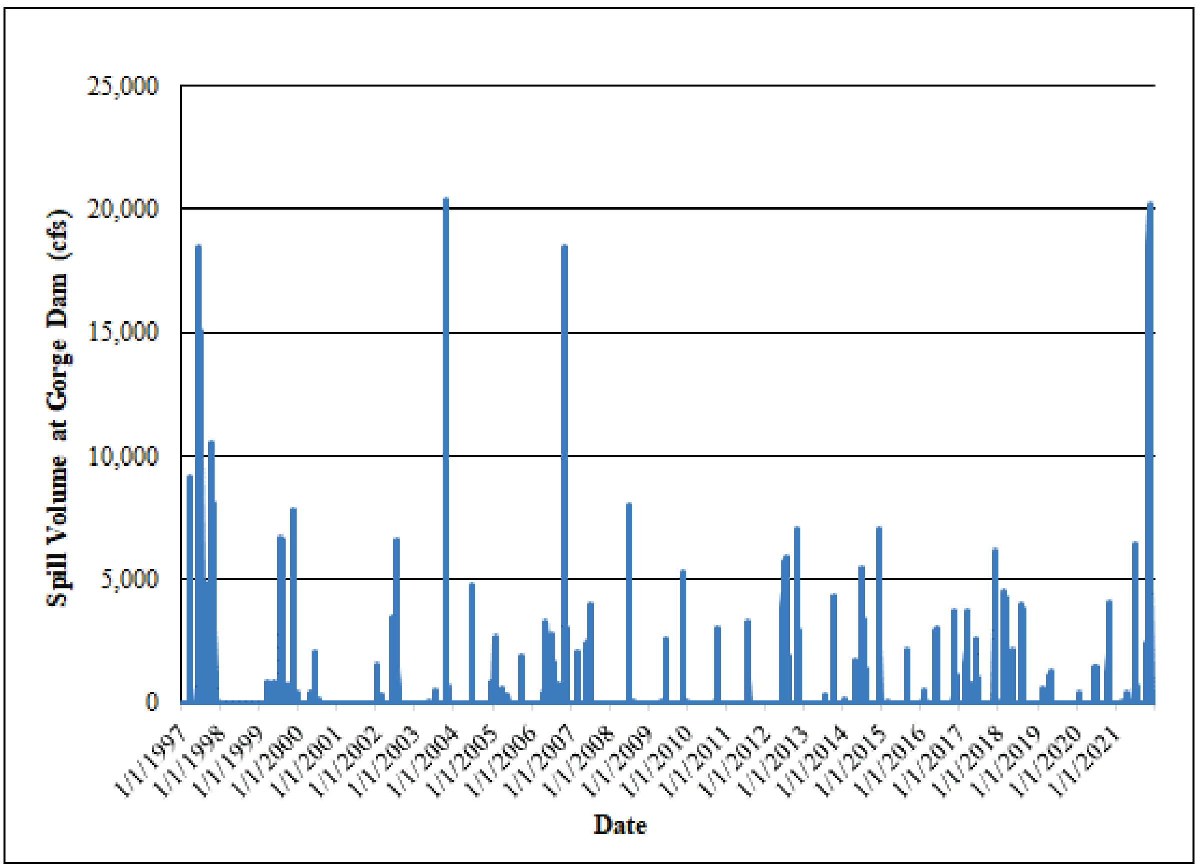



**Figure 5.2-23. Spill events at Gorge Dam (1997-2021).**

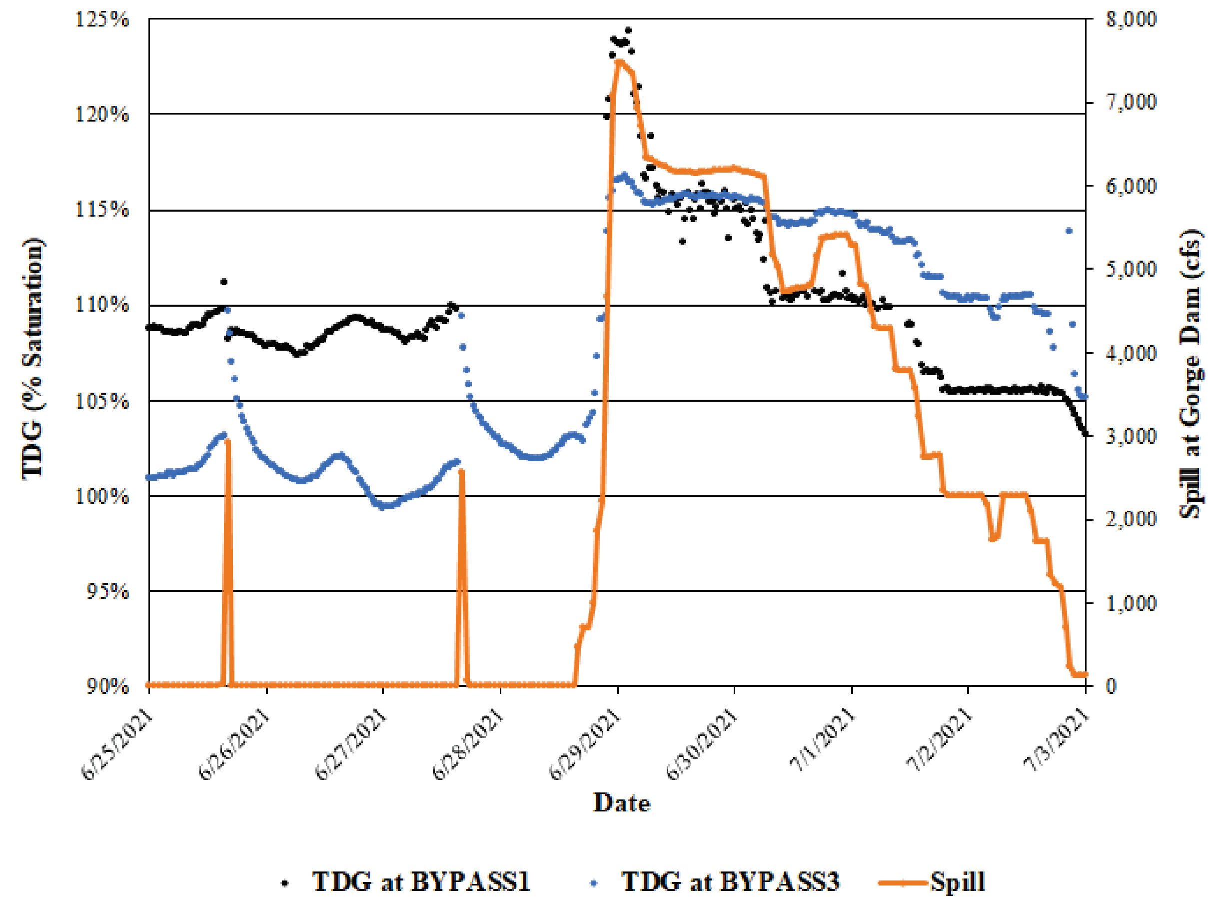



**Figure 5.2-24.** **TDG and spill in the Gorge bypass reach (BYPASS1 and 3) (late June/early July 2021).**

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 5.2-25). 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; 22 percent of spill events recorded from 1997-2021 have exceeded 4,000 cfs.

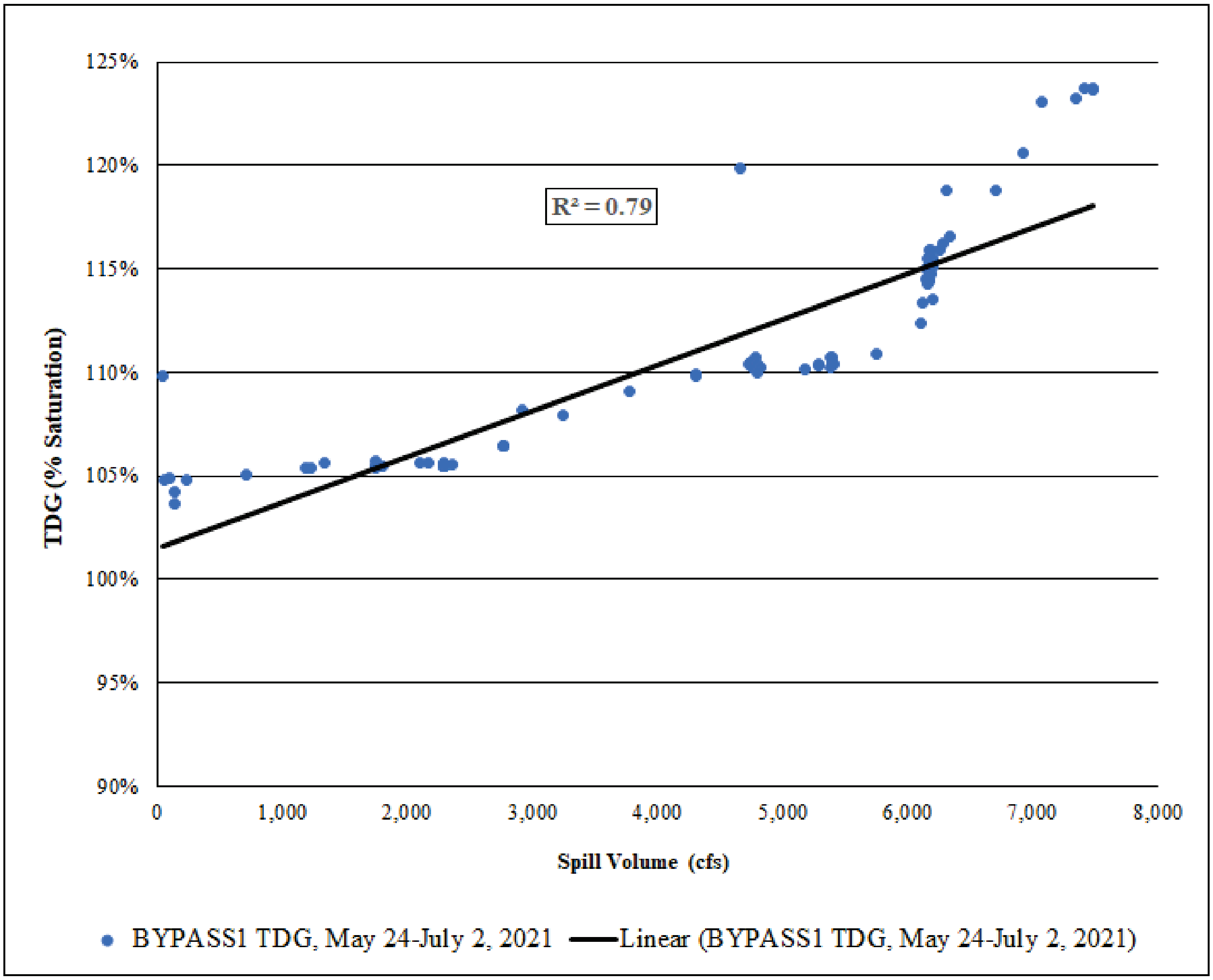



**Figure 5.2-25. Regression of TDG at BYPASS1 vs. spill at Gorge Dam (May 24-July 2, 2021).**

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 2023c). 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 99 and 102 percent saturation, increasing to 106 percent saturation with the onset of the 1,200 cfs release (Figure 5.2-26). 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 saturation over the four-day release.

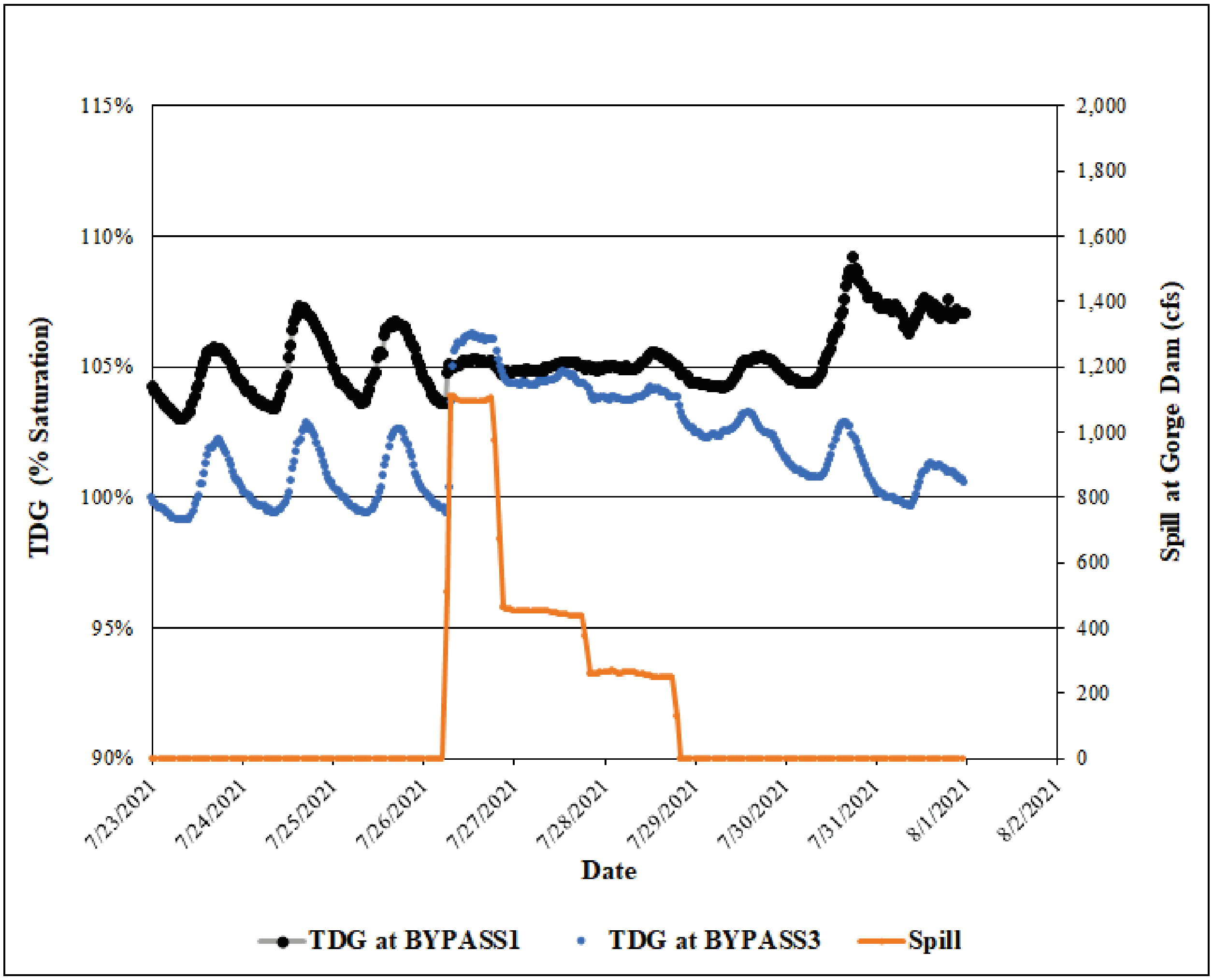



**Figure 5.2-26. TDG at BYPASS1 and BYPASS3 during planned spill at Gorge Dam (July 2021).**

### 5.2.5.2 Spill Monitoring Downstream of Gorge Dam

As noted in Section 4.1.6, TDG monitoring at the Gorge bypass reach and Powerhouse locations is being augmented with measurement of TDG during spill events at locations downstream of Gorge Dam. These measurements are opportunistic; not all spill events are monitored. Measurements of TDG during spill have been taken from the Gorge Dam access bridge, Gorge Powerhouse access bridge, Ladder Creek Falls Bridge, the suspension bridge to Trail of the Cedars, or the bridge at Newhalem Campground. Preliminary data from spill events monitored in October and November 2021 and July 2022 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 reservoir 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 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 DS5 sonde.

Start and end times and Skagit River flows at the USGS Newhalem gage (12178000) during the monitoring periods are shown below (Table 5.2-1). The first 30 minutes of data collected at Ladder Creek Falls Bridge (LADDER1) were removed during QA/QC when TDG values were equilibrating. Skagit River flow (Gorge Powerhouse generation and spill combined) and spill at Gorge Dam remained constant at approximately 8,600 cfs and 2,000 cfs, respectively.

**Table 5.2-1. Locations, times, and Skagit River flow at the USGS Newhalem gage (12178000) during TDG monitoring (October 26, 2021).**

| Site ID | Start Time | End Time | Flow at Newhalem (cfs) |
|---|---|---|---|
| LADDER1 | 09:00[1] | 11:00 | 8,580 – 8,640 |
| CEDARS1 | 11:30 | 13:30 | 8,610 – 8,530 |
| NEWCG1 | 14:00 | 16:00 | 8,560 – 8,610 |

1 The first 30 minutes of data at LADDER1 were removed during QA/QC for sonde equilibration.

TDG at all three bridge sites remained at or near 105 percent saturation (Figure 5.2-27). Hydrolab sondes recording TDG data in the Gorge bypass reach could not be accessed at the time due to a combination of high flows, landslides, and road closures. These units were not recovered.

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 (12178000) during the monitoring period were between 4,500 and 4,600 cfs.

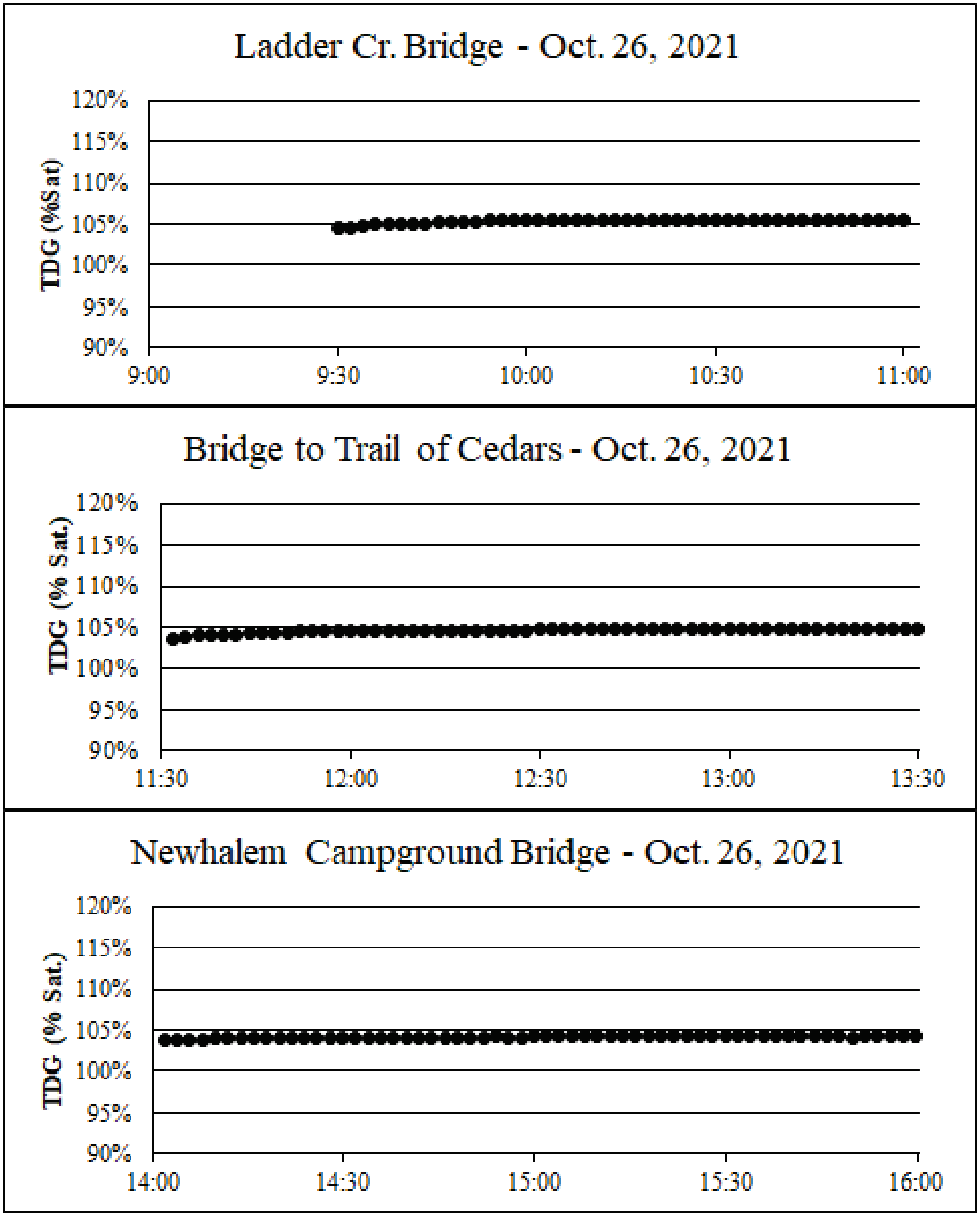



**Figure 5.2-27. TDG sampled at bridges downstream of Gorge Powerhouse during planned spill of approximately 2,000 cfs (October 26, 2021). Flow at USGS Newhalem gage (12178000) was approximately 8,600 cfs throughout this period.**

In addition to the 2021 events, TDG was measured at bridges during spill on July 5, 2022. Given loss or damage of the Gorge bypass reach sondes during late fall 2021 spill events, including the sonde at the plunge pool (BYPASS1), City Light added spill monitoring locations at the Gorge Dam Access Bridge near the upstream end of the Gorge bypass reach, just downstream of Gorge Dam and Gorge Powerhouse access bridge, located just upstream from Gorge Powerhouse. Other sites monitored during the July spill event included Ladder Creek Bridge (LADDER1), and the Bridge to Trail of the Cedars (CEDARS1); the latter two were also monitored in 2021. Spill at Gorge Dam on July 5, 2022 averaged 5,400 cfs and discharge recorded by the USGS Newhalem gage (12178000) was fairly constant over the course of the day (Table 5.2-2).

**Table 5.2-2. Locations, times, and Skagit River flow at the USGS Newhalem gage (12178000) during TDG monitoring (July 5, 2022).**

| Site ID | Start Time | End Time | Flow at Newhalem (cfs) |
|---|---|---|---|
| Gorge Dam Access | 9:00 | 10:30 | 12,400 – 12,900 |
| Gorge Powerhouse Access | 11:00 | 12:00 | 12,600 – 12,900 |
| LADDER1 | 12:40 | 13:40 | 12,400 – 12,800 |
| CEDARS1 | 14:00 | 15:15 | 12,400 – 12,800 |

Spill monitoring at LADDER1 was not possible during the July 5, 2022 event due to high flows from combined spill and generation preventing the sonde from reaching compensation depth.

As in 2021, TDG was recorded on July 5, 2022 at 2-minute intervals over approximately an hour-long period at each site. Results for the event are shown below (Figure 5.2-28). Levels were highest at the Gorge Dam Access Bridge, where TDG remained between 110 and 115 percent saturation for most of the monitoring period. TDG remained close to but less than 110 percent saturation at the three downstream bridges, including the Gorge Powerhouse Access Bridge, which is upstream from the Gorge Powerhouse inflow and reflects only water from the bypass reach, and the Bridge to Trail of the Cedars (CEDARS1), downstream of the mixing zone of the two inflows.

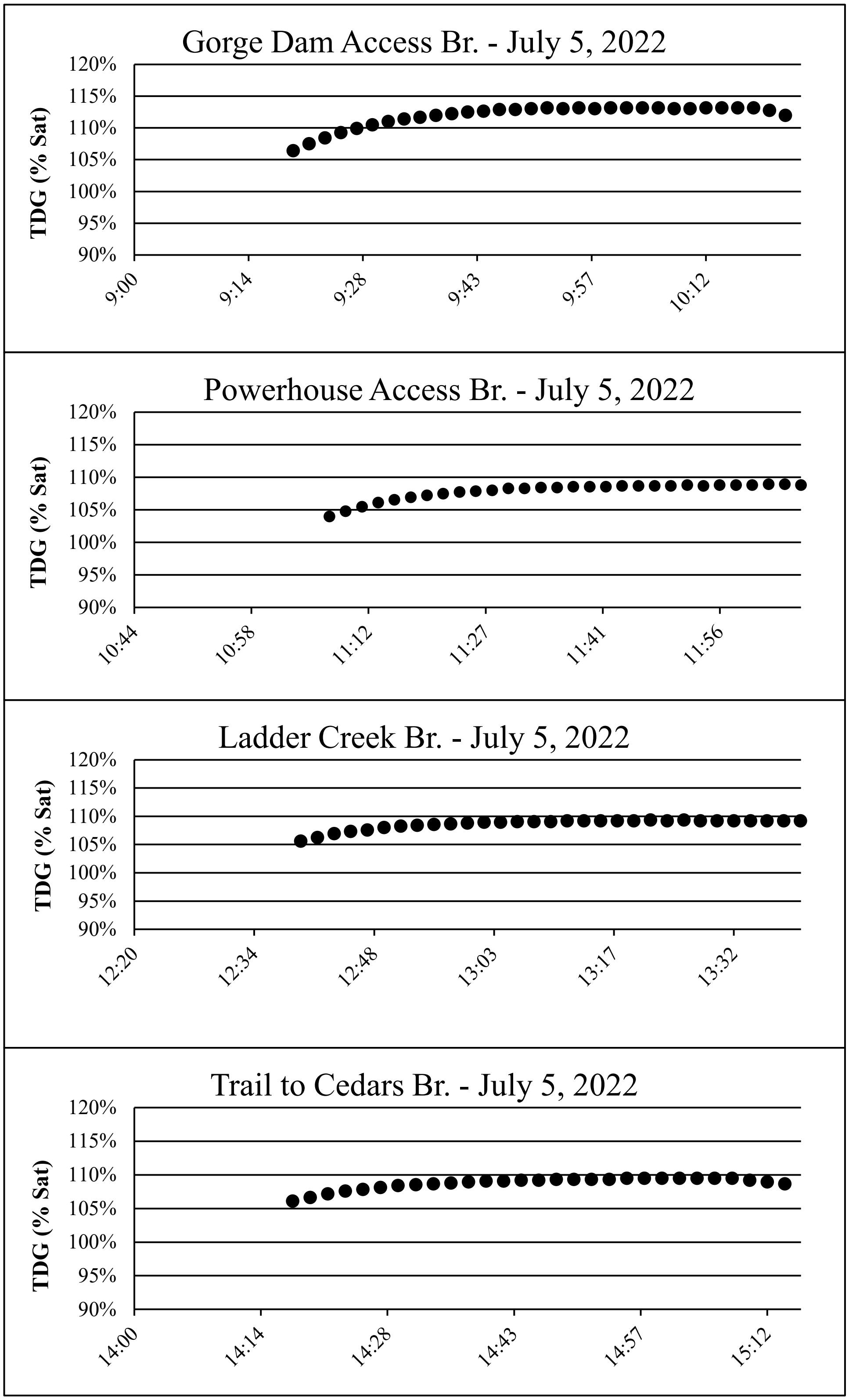



**Figure 5.2-28. TDG levels at bridge sites during spill of approximately 5,400 cfs at Gorge Dam (July 5, 2022). Flow at USGS Newhalem gage (12178000) was approximately 12,700 cfs throughout this period.**

### 5.2.6 Zooplankton

During 2022, zooplankton samples were collected at Gorge Powerhouse on June 22, July 21, August 10, September 8, October 27, and November 16. All samples from June through October were taken with a 500 µ drift net with an 18-inch by 12-inch rectangular opening, the same net used for sampling macroinvertebrate drift. In November 2022 to evaluate sampling bias, a 64 µ Wisconsin-style plankton net with a 20 cm diameter opening, which is used to sample zooplankton in Ross, Diablo, and Gorge lakes, was deployed consecutively with the drift net. Zooplankton data will be analyzed further when the complete set of taxonomic data is available.

### 5.2.7 Benthic and Drifting Macroinvertebrates

Benthic macroinvertebrates were collected with a kicknet in the Gorge bypass reach in June, September, and October 2022. Eight 1 $ft^2$ kicknet samples were taken during each sampling event for a single 8 $ft^2$ composite sample. Available data for the June and September events (June 16 and September 1), indicate that abundance in June was over twice as high as seen in Stetattle Creek; however, both taxa richness and percent EPT composition were lower than observed for Stetattle Creek or the Skagit River main channel sites downstream of Gorge Powerhouse (Figure 5.2-29). Percent EPT composition in the bypass reach was comparatively low: 6 percent in June and 17 percent in September. The top three dominant species (by number) for the June event, and the top two dominant species in September were chironomids. A capniid stonefly was the third most dominant species in September. Gatherers were the dominant functional group for both June and September events (71 percent and 60 percent, respectively), followed by shredders (17 percent during both events) (Figure 5.2-30).

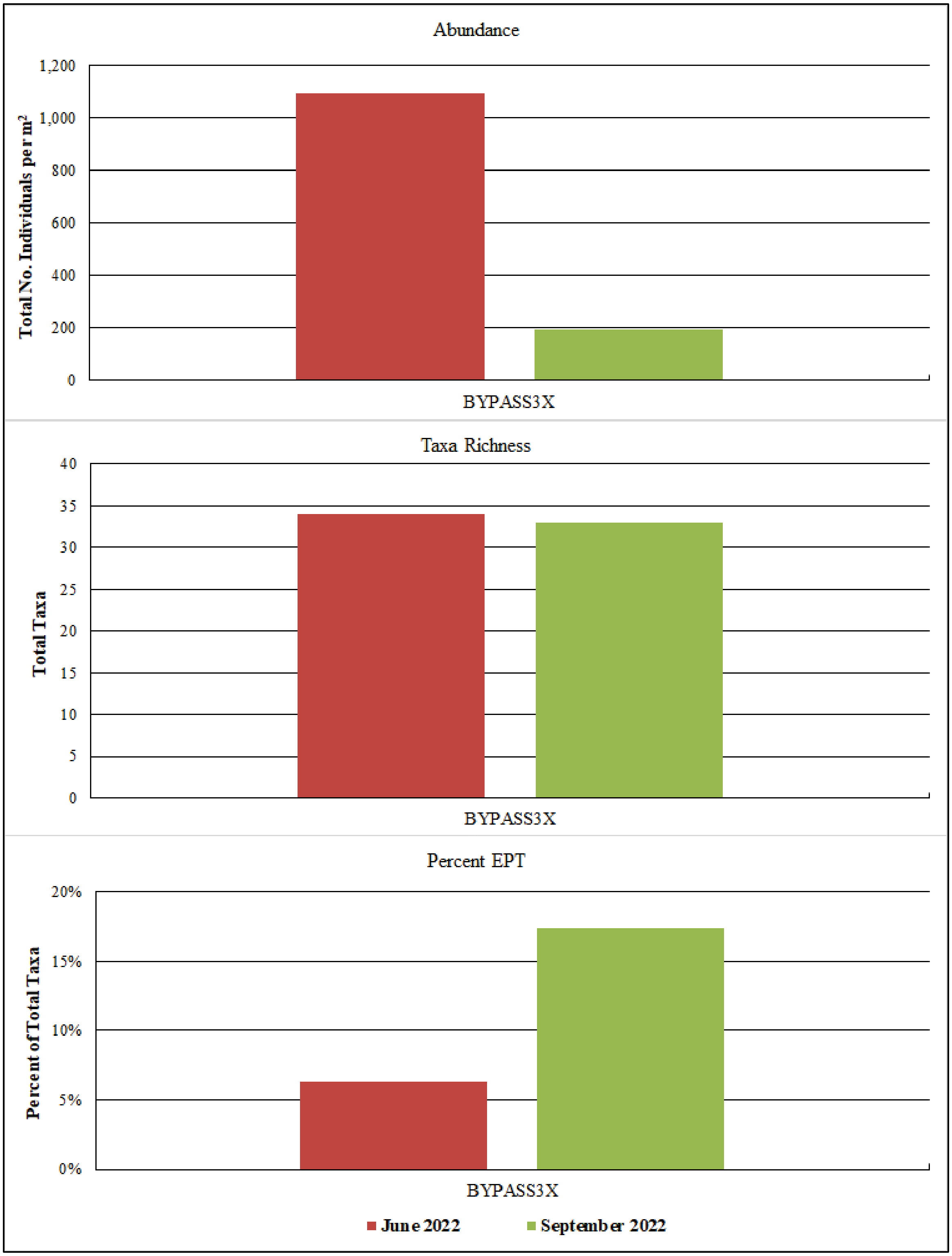



**Figure 5.2-29.** **Abundance (top), taxa richness (middle), and percent EPT composition (bottom) of composited samples collected at BYPASS3X (June and September 2022).**

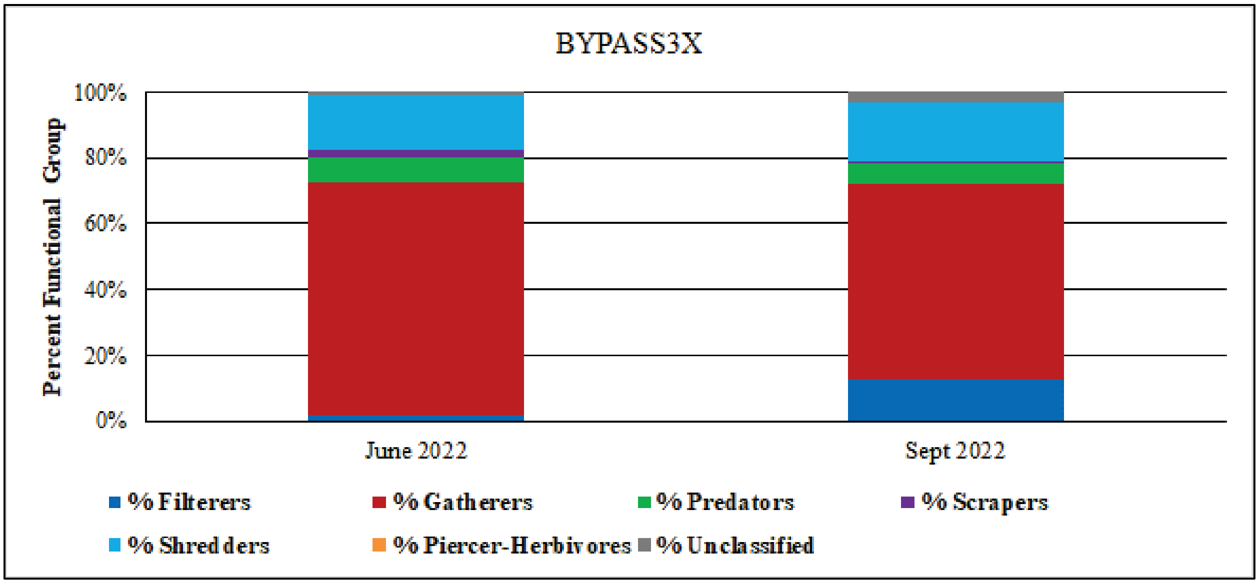



**Figure 5.2-30. Functional group composition at BYPASS3X (June and September 2022).**

### 5.2.8 QA/QC

Data quality for continuously monitoring sondes was assessed by mid-deployment performance checks at an interval of approximately every three to four weeks. With the exception of the performance test for turbidity on September 8, 2021 (covering the period from August 17 to September 8), all performance tests on sondes 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 performance checks at other sites were followed by re-calibration for all but (1) turbidity at BYPASS3 on September 8, 2021 and PHOUSE1 on August 10, 2022 and (2) pH at PHOUSE1 on August 17 and October 5, 2021 and July 19, 2022.

As described in Section 4.2, if a parameter did not meet performance standards during a mid-deployment performance check, all data extending back to the last passed performance test or recalibration are qualified, but not removed from processed data.

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 in 2021 (Table 5.2-3). The low percent completion for all parameters at PHOUSE1 in 2021 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 almost all either qualified (due to failure of the performance evaluation checks, most likely caused by leaching of the electrolyte in the pH sensor) or rejected due to battery failure. A total of 1,054 data points were rejected for DO at PHOUSE1 in 2022, higher than any other parameter. The DO sensor requires more battery to measure a data point than other sensors and the sonde records an erroneous DO value when battery life is limited. Data measured by other sensors remains valid during these measurements. The erroneous data points and all rejected data have been removed from analysis and not included in this report.

Similarly, a large number of TDG readings at PHOUSE1 are qualified. As discussed in Section 5.1.3.5, the high number of qualified measurements is due to failed performance tests conducted in the field. A long equilibration time is necessary for TDG sensors, and performance tests of longer duration would have resulted in fewer failed tests, thus the impact on data quality and overall confidence in terms of accurately characterizing TDG at PHOUSE1 are deemed negligible.

**Table 5.2-3. Percent data completeness results for the Gorge bypass reach (BYPASS1-3) and Powerhouse (PHOUSE1) (January 28-October 5, 2021 and January 26-September 27, 2022).**

| Parameter | Site | Accepted | Qualified | Rejected | Total Planned Results | Percent Complete |
|---|---|---|---|---|---|---|
| **2021** | | | | | | |
| 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% |
| **2022** | | | | | | |
| Temperature | PHOUSE1 | 10,560 | 0 | 82 | 11,382 | 92.8% |
| DO | PHOUSE1 | 9,566 | 762 | 1,054 | 11,382 | 90.8% |
| TDG | PHOUSE1 | 6,255 | 4,290 | 837 | 11,382 | 92.6% |
| Turbidity | PHOUSE1 | 9,295 | 1,260 | 827 | 11,382 | 92.7% |
| pH | PHOUSE1 | 6,126 | 4,434 | 822 | 11,382 | 92.8% |

A summary of data collection outcomes during the period reported in this study report, from January 28, 2021 to October 31, 2022, is shown below (Figure 5.2-31 and 5.2-32). The charts for each parameter and site display whether data collected during a given week are on average 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), no data were collected at BYPASS2. Supply chain issues delayed sonde deployment at BYPASS2 until early August 2021. High flows were an important factor limiting access for battery replacement, and therefore limiting data collection at the PHOUSE1 and BYPASS3 sites in early to mid-July 2021. In general, the charts below show that the majority of data collected at each site are accepted. The greatest number of qualified observations are for TDG due to failure during performance tests during mid-deployment checks. However, as with the Gorge Lake sondes, experience has shown that a long equilibration time is necessary for TDG sensors, and performance tests of longer duration would have resulted in fewer failed tests. PHOUSE1 has the greatest number of rejected observations due to extended periods of exposure, battery failure, leaching of pH reference electrode, and TDG values that appeared inaccurate and therefore rejected.

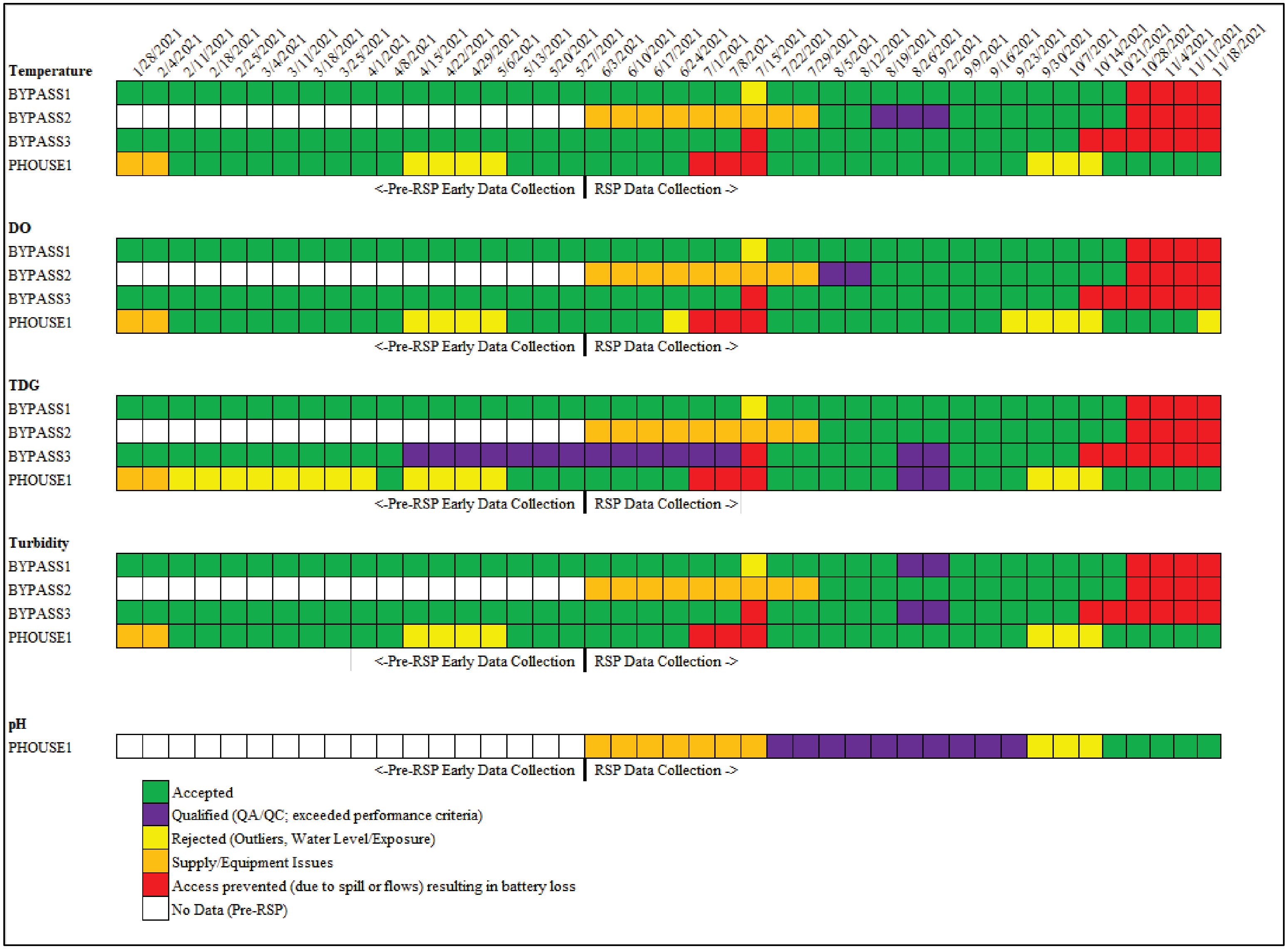



**Figure 5.2-31. Weekly summary of data collection outcomes for continuous monitoring at the Gorge bypass reach (BYPASS1-3) and Gorge Powerhouse (PHOUSE1) sites (January 28-October 5, 2021).**

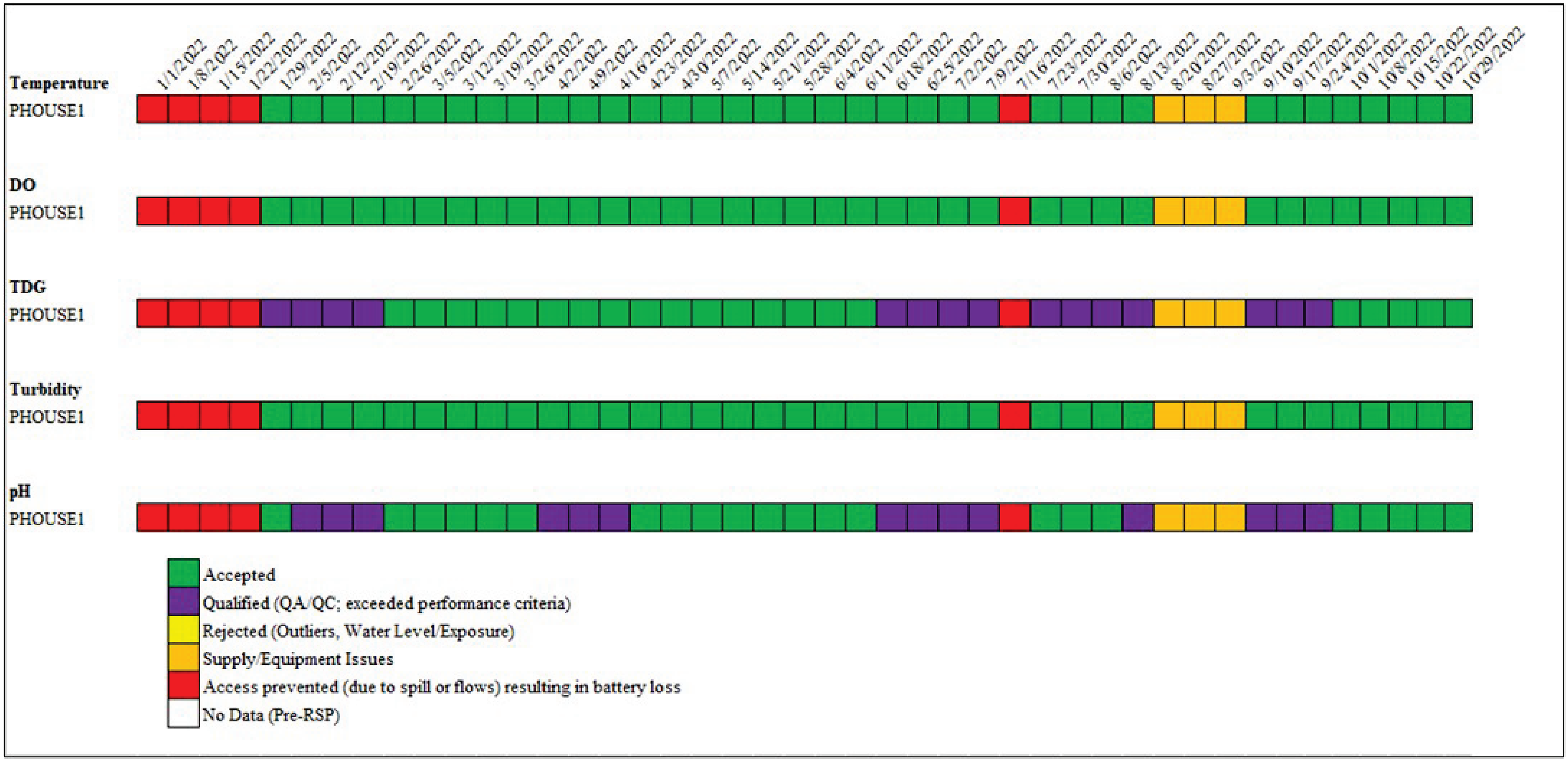



**Figure 5.2-32. Weekly summary of data collection outcomes for continuous monitoring at Gorge Powerhouse (PHOUSE1) (January 1-October 31, 2022).**

## 5.3 Skagit and Sauk Rivers Downstream of Gorge Powerhouse

This section of the study report addresses monitoring activities in the Skagit River downstream of Gorge Powerhouse, including continuous water temperature, DO, pH, specific conductance, and turbidity monitoring, results of water quality grab samples, periphyton sampling, and benthic and drifting macroinvertebrate sample collection.

### 5.3.1 Water Temperature

#### 5.3.1.1 Main Channel Temperatures

As described in Section 4.1.7, Onset temperature loggers (thermographs) were deployed at six sites in the Skagit River downstream of Gorge Powerhouse and at one site in the lower Sauk River in 2021. In 2022, thermographs were deployed at the same sites and at two additional Skagit River sites and one additional Sauk River site. 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 between Newhalem and Concrete. The two sites added in 2022 were deployed downstream of Concrete near Hamilton at PRM 42.2 (SKAGIT8) and downstream from the SR 9 Bridge near Sedro Woolley at PRM 23.1 (SKAGIT9).

The monthly minimum, mean, and maximum water temperatures for each site during the monitoring period are reported in Table 5.3-1. Thirty-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, 2021. 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. The thermograph at the SAUK2 site was out of the water during a visit, and it is presumed the thermograph was removed from the water by hand and left on the shoreline.

One thermograph (SKAGIT5) was lost during high flows in winter 2021. No data are available for this location from September 28, 2021 until April 2021, when the thermograph was replaced. Continued erosion at the site dislodged the replacement thermograph shortly after deployment. The unit was subsequently re-deployed on July 26, 2022 at a site downstream with a more stable shoreline. 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.

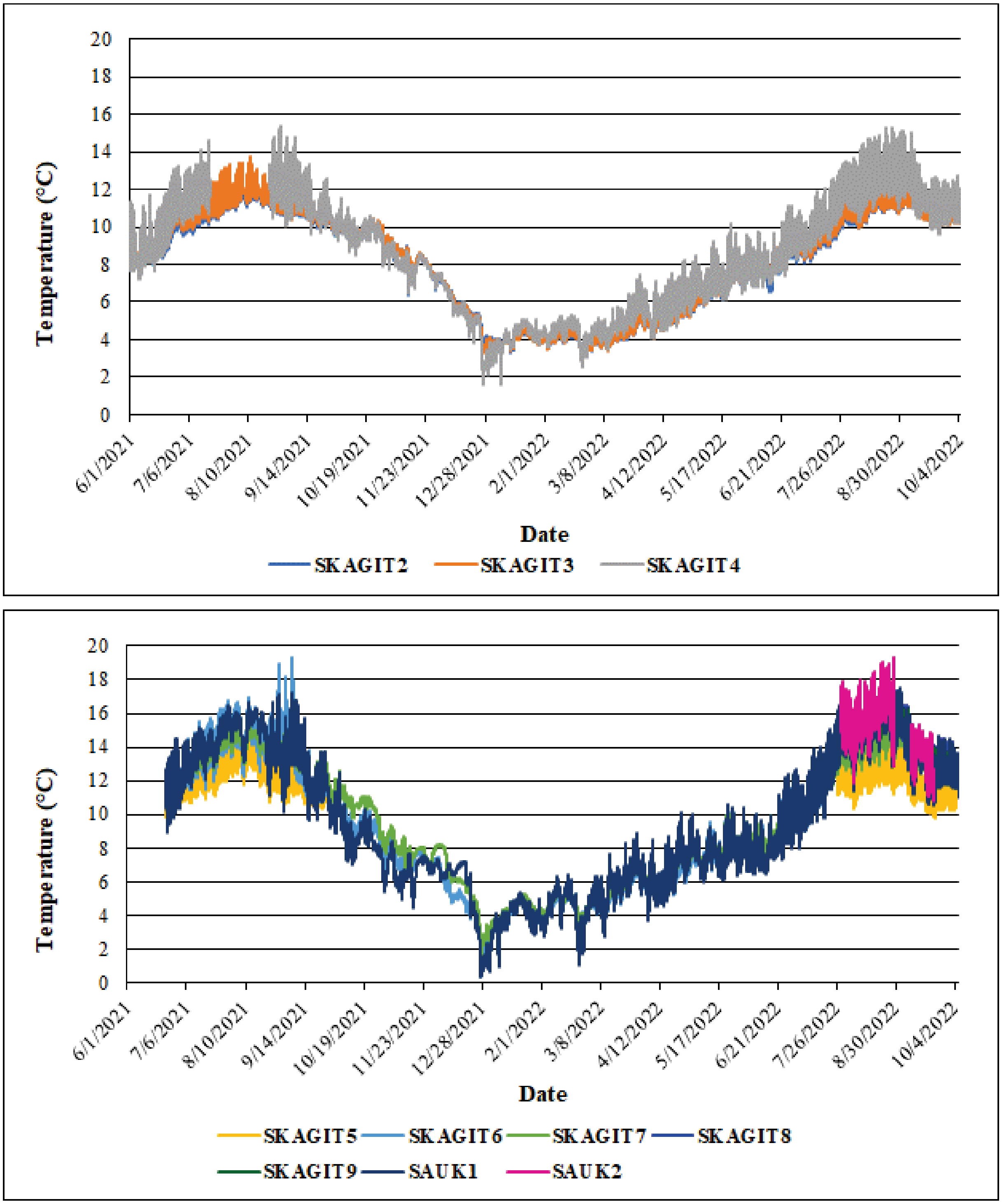
All thermograph sites are located well downstream of any tributaries and reflect conditions within the Skagit River. Only the thermograph deployed at PRM 60.8 (SKAGIT6) is in an area that is occasionally not well mixed. Large woody debris has racked on the shoreline; smaller branches and fine sediment accumulate to form a small backwater pool, which may cause localized warming at lower river flows. This area is cleared of accumulation during higher river flows.

**Table 5.3-1. Monthly minimum, mean, and maximum hourly water temperatures recorded at lower Skagit River and Sauk River monitoring sites (June 2021-September 2022).**

| Month 2021 | 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 RM 5.4 | 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 RM 5.4 | 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 RM 5.4 | 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 RM 5.4 | 9.7 | 12.9 | 17.3 |
| October | SKAGIT2 | PRM 91.6 | 8.1 | 9.7 | 10.3 |
| | SKAGIT3 | PRM 85.9 | 8.2 | 9.8 | 10.6 |
| | SKAGIT4 | PRM 75.6 | 8.0 | 9.6 | 11.6 |
| | SKAGIT5 | PRM 69.3 | - | - | - |
| | SKAGIT6 | PRM 60.8 | 7.3 | 9.4 | 12.0 |
| | SKAGIT7 | PRM 54.5 | 7.9 | 10.6 | 12.6 |
| | SAUK1 | Sauk RM 5.4 | 5.4 | 8.7 | 12.5 |
| November | SKAGIT2 | PRM 91.6 | 6.5 | 8.2 | 9.4 |
| | SKAGIT3 | PRM 85.9 | 6.7 | 8.2 | 9.4 |
| | SKAGIT4 | PRM 75.6 | 6.5 | 8.0 | 9.2 |
| | SKAGIT5 | PRM 69.3 | - | - | - |

| Month 2021 | Site ID | Location | Min Water Temp (°C) | Mean Water Temp (°C) | Max Water Temp (°C) |
|---|---|---|---|---|---|
| | SKAGIT6 | PRM 60.8 | 6.5 | 7.4 | 8.8 |
| | SKAGIT7 | PRM 54.5 | 6.8 | 7.9 | 9.3 |
| | SAUK1 | Sauk RM 5.4 | 4.5 | 6.7 | 8.4 |
| December | SKAGIT2 | PRM 91.6 | 3.8 | 5.6 | 7.4 |
| | SKAGIT3 | PRM 85.9 | 3.4 | 5.5 | 7.5 |
| | SKAGIT4 | PRM 75.6 | 1.7 | 5.2 | 7.6 |
| | SKAGIT5 | PRM 69.3 | - | - | - |
| | SKAGIT6 | PRM 60.8 | 1.1 | 4.8 | 7.5 |
| | SKAGIT7 | PRM 54.5 | 1.7 | 5.6 | 8.2 |
| | SAUK1 | Sauk RM 5.4 | 0.3 | 5.3 | 7.4 |
| **2022** | | | | | |
| January | SKAGIT2 | PRM 91.6 | 3.3 | 4.1 | 4.6 |
| | SKAGIT3 | PRM 85.9 | 2.8 | 4.0 | 4.6 |
| | SKAGIT4 | PRM 75.6 | 1.6 | 4.2 | 5.1 |
| | SKAGIT5 | PRM 69.3 | - | - | - |
| | SKAGIT6 | PRM 60.8 | 2.0 | 4.0 | 5.2 |
| | SKAGIT7 | PRM 54.5 | 2.5 | 4.2 | 5.3 |
| | SAUK1 | Sauk RM 5.4 | 0.8 | 3.8 | 5.3 |
| February | SKAGIT2 | PRM 91.6 | 3.1 | 3.9 | 4.4 |
| | SKAGIT3 | PRM 85.9 | 3.0 | 4.0 | 4.6 |
| | SKAGIT4 | PRM 75.6 | 2.6 | 4.3 | 5.3 |
| | SKAGIT5 | PRM 69.3 | - | - | - |
| | SKAGIT6 | PRM 60.8 | 2.1 | 4.4 | 5.7 |
| | SKAGIT7 | PRM 54.5 | 3.3 | 4.6 | 5.5 |
| | SAUK1 | Sauk RM 5.4 | 1.1 | 4.3 | 6.4 |
| March | SKAGIT2 | PRM 91.6 | 3.5 | 4.2 | 5.9 |
| | SKAGIT3 | PRM 85.9 | 3.4 | 4.3 | 6.3 |
| | SKAGIT4 | PRM 75.6 | 3.5 | 5.0 | 7.5 |
| | SKAGIT5 | PRM 69.3 | - | - | - |
| | SKAGIT6 | PRM 60.8 | 3.3 | 5.4 | 7.9 |
| | SKAGIT7 | PRM 54.5 | 4.3 | 5.6 | 7.2 |
| | SAUK1 | Sauk RM 5.4 | 2.8 | 5.8 | 8.9 |
| April | SKAGIT2 | PRM 91.6 | 4.2 | 5.2 | 6.4 |
| | SKAGIT3 | PRM 85.9 | 4.1 | 5.3 | 7.0 |
| | SKAGIT4 | PRM 75.6 | 4.1 | 5.9 | 8.2 |
| | SKAGIT5 | PRM 69.3 | - | - | - |
| | SKAGIT6 | PRM 60.8 | 4.4 | 6.4 | 9.1 |
| | SKAGIT7 | PRM 54.5 | 5.4 | 6.6 | 8.0 |
| | SAUK1 | Sauk RM 5.4 | 3.8 | 6.6 | 10.1 |
| May | SKAGIT2 | PRM 91.6 | 5.7 | 6.8 | 8.4 |
| | SKAGIT3 | PRM 85.9 | 5.8 | 6.6 | 8.0 |

| Month 2021 | Site ID | Location | Min Water Temp (°C) | Mean Water Temp (°C) | Max Water Temp (°C) |
|---|---|---|---|---|---|
| | SKAGIT4 | PRM 75.6 | 5.9 | 7.1 | 9.2 |
| | SKAGIT5 | PRM 69.3 | - | - | - |
| | SKAGIT6 | PRM 60.8 | 6.1 | 7.9 | 10.5 |
| | SKAGIT7 | PRM 54.5 | 7.0 | 7.7 | 8.5 |
| | SAUK1 | Sauk RM 5.4 | 6.0 | 7.8 | 10.6 |
| June | SKAGIT2 | PRM 91.6 | 6.6 | 7.9 | 9.6 |
| | SKAGIT3 | PRM 85.9 | 7.0 | 8.2 | 9.9 |
| | SKAGIT4 | PRM 75.6 | 6.8 | 8.4 | 11.1 |
| | SKAGIT5 | PRM 69.3 | - | - | - |
| | SKAGIT6 | PRM 60.8 | 6.9 | 8.7 | 11.8 |
| | SKAGIT7 | PRM 54.5 | 7.5 | 9.1 | 11.6 |
| | SAUK1 | Sauk RM 5.4 | 6.5 | 8.5 | 12.4 |
| July | SKAGIT2 | PRM 91.6 | 8.2 | 9.5 | 11.1 |
| | SKAGIT3 | PRM 85.9 | 8.3 | 9.8 | 11.7 |
| | SKAGIT4 | PRM 75.6 | 8.4 | 10.6 | 13.5 |
| | SKAGIT5 | PRM 69.3 | 11.2 | 12.5 | 14.0 |
| | SKAGIT6 | PRM 60.8 | 8.6 | 10.7 | 12.9 |
| | SKAGIT7 | PRM 54.5 | 9.8 | 11.8 | 14.9 |
| | SAUK1 | Sauk RM 5.4 | 8.0 | 12.3 | 17.1 |
| August | SKAGIT2 | PRM 91.6 | 10.0 | 11.0 | 12.0 |
| | SKAGIT3 | PRM 85.9 | 10.0 | 11.3 | 12.9 |
| | SKAGIT4 | PRM 75.6 | 10.3 | 12.8 | 15.3 |
| | SKAGIT5 | PRM 69.3 | 10.4 | 12.8 | 15.2 |
| | SKAGIT6 | PRM 60.8 | - | - | - |
| | SKAGIT7 | PRM 54.5 | 11.4 | 14.3 | 16.0 |
| | SKAGIT8 | PRM 42.2 | 14.7 | 15.7 | 17.3 |
| | SKAGIT9 | PRM 23.1 | 14.1 | 14.9 | 15.9 |
| | SAUK1 | Sauk RM 5.4 | 11.5 | 15.3 | 18.1 |
| | SAUK2 | Sauk RM 13.2 | 10.8 | 15.9 | 19.3 |
| September | SKAGIT2 | PRM 91.6 | 10.0 | 10.7 | 12.1 |
| | SKAGIT3 | PRM 85.9 | 10.0 | 10.8 | 12.9 |
| | SKAGIT4 | PRM 75.6 | 9.7 | 11.7 | 15.1 |
| | SKAGIT5 | PRM 69.3 | 9.9 | 11.7 | 14.7 |
| | SKAGIT6 | PRM 60.8 | - | - | - |
| | SKAGIT7 | PRM 54.5 | 11.6 | 13.1 | 15.8 |
| | SKAGIT8 | PRM 42.2 | 12.0 | 13.6 | 17.2 |
| | SKAGIT9 | PRM 23.1 | 12.0 | 13.3 | 14.1 |
| | SAUK1 | Sauk RM 5.4 | 10.6 | 13.4 | 17.6 |
| | SAUK2 | Sauk RM 13.2 | 10.9 | 13.6 | 15.4 |




Note: SKAGIT4 was dewatered from mid-July through mid-August 2021. SKAGIT5 was lost in winter 2021 due to high flows and replaced in July 2022. SKAGIT8-9 and SAUK2 were not deployed until July 2022. SKAGIT4 and SAUK2 were dewatered for short periods.

**Figure 5.3-1. 30-minute water temperatures at Skagit River sites upstream from Marblemount (SKAGIT2-4, top) (June 2021-September 2022), 30-minute water temperatures at Skagit River sites from Marblemount downstream to Concrete including the Sauk River site (SKAGIT5-7, SAUK1, bottom) (June 2021-September 2022).**

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 Newhalem gage (12178000), the gage that is closest to these two sites.

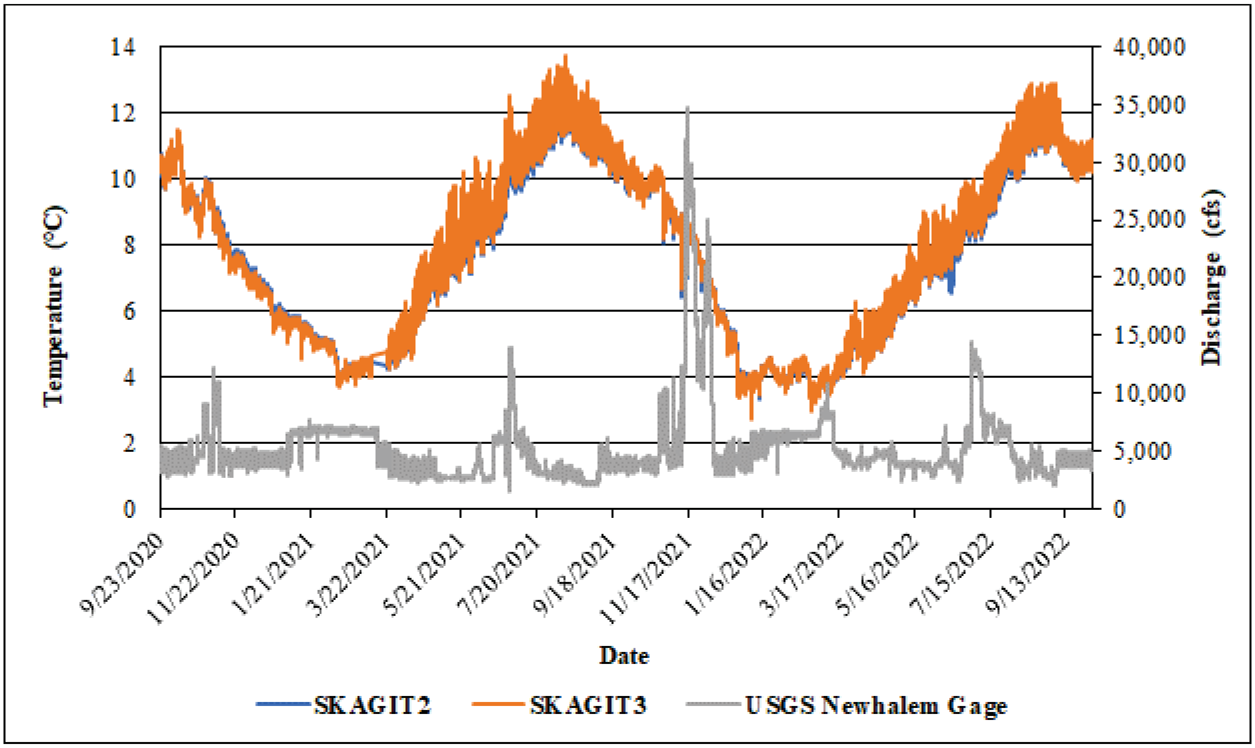



**Figure 5.3-2. 30-minute water temperatures at SKAGIT2 and 3 (PRM 91.6 and 85.9) and Skagit River discharge monitored at the USGS Newhalem gage (12178000) (September 2020-September 2022).**

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 (12181000), 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 USGS Sauk River gage (12189500).

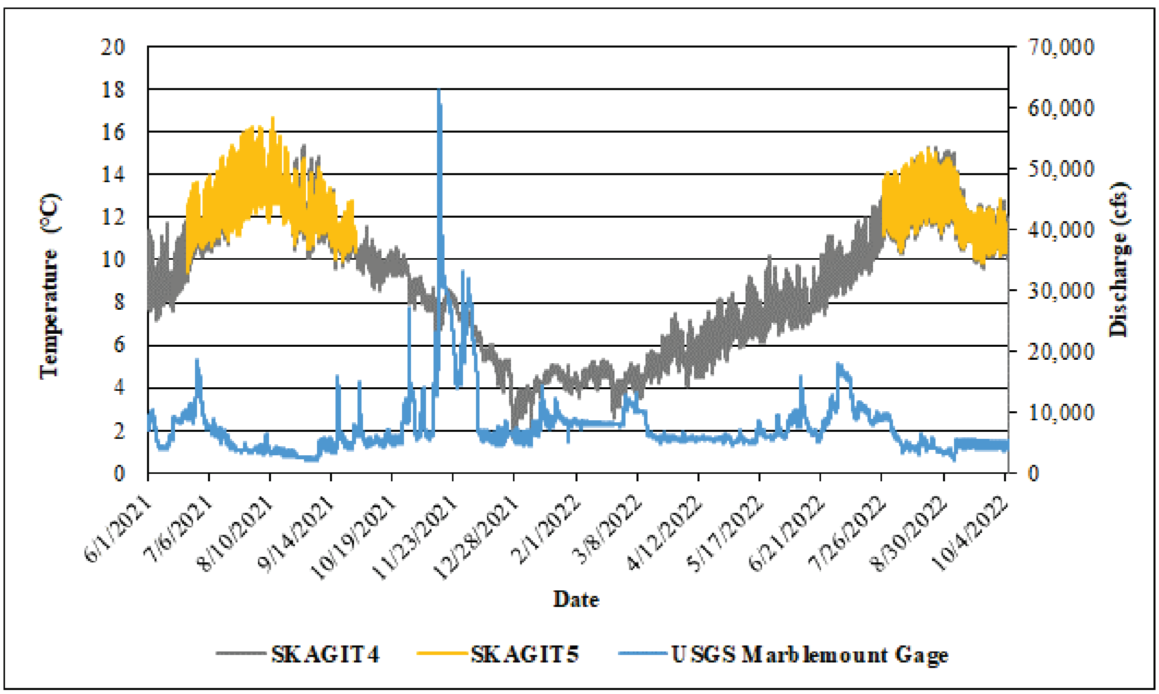
The Baker River enters the Skagit River approximately 2.2 miles upstream of PRM 54.5 (SKAGIT7). Flows in the Baker River are managed by the Baker River Hydroelectric Project (owned and operated by Puget Sound Energy) and are typically between 1,000 and 5,600 cfs.

Figure 5.3-5 shows water temperatures at PRM 54.5 (SKAGIT7) and the flows recorded in the Skagit River at Concrete USGS gage (12194000) and the Baker River flow recorded at the Baker River USGS gage at Henry Thompson Bridge at Concrete (12193400).

The downstream Sauk River thermograph (SAUK1) is located approximately 5.4 miles upstream of the Skagit River confluence, coincident with the USGS Sauk River gage; the upstream Sauk River thermograph (SAUK2) is located upstream of the confluence with the Suiattle River at approximately RM 13.2. Figure 5.3-6 shows water temperatures at the Sauk River sites (SAUK1 and 2) and flows at the USGS Sauk River gage.

Water temperatures at the new thermograph sites downstream of Concrete near Hamilton at PRM 42.2 (SKAGIT8) and downstream from the SR 9 Bridge near Sedro Woolley at PRM 23.1 (SKAGIT9) are shown below (Figure 5.3-7), along with flows at the Skagit River at USGS Mount Vernon gage (12200500).

Time series of 7-DADMax temperatures at Skagit and Sauk river sites are shown below (Figure 5.3-8), 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 in the Skagit River during the monitoring period was 17.2°C (at SKAGIT6 (PRM 60.8) at the end of August 2021) and the highest 7-DADMax water temperature recorded in the Sauk River was 18.5°C (at SAUK2 upstream from the confluence with the Suiattle River) (Table 5.3-2).




Note: SKAGIT4 was dewatered from mid-July through mid-August 2021. SKAGIT5 was lost in winter 2021 due to high flows and replaced in July 2022.

**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 (12181000) (June 2021-September 2022).**

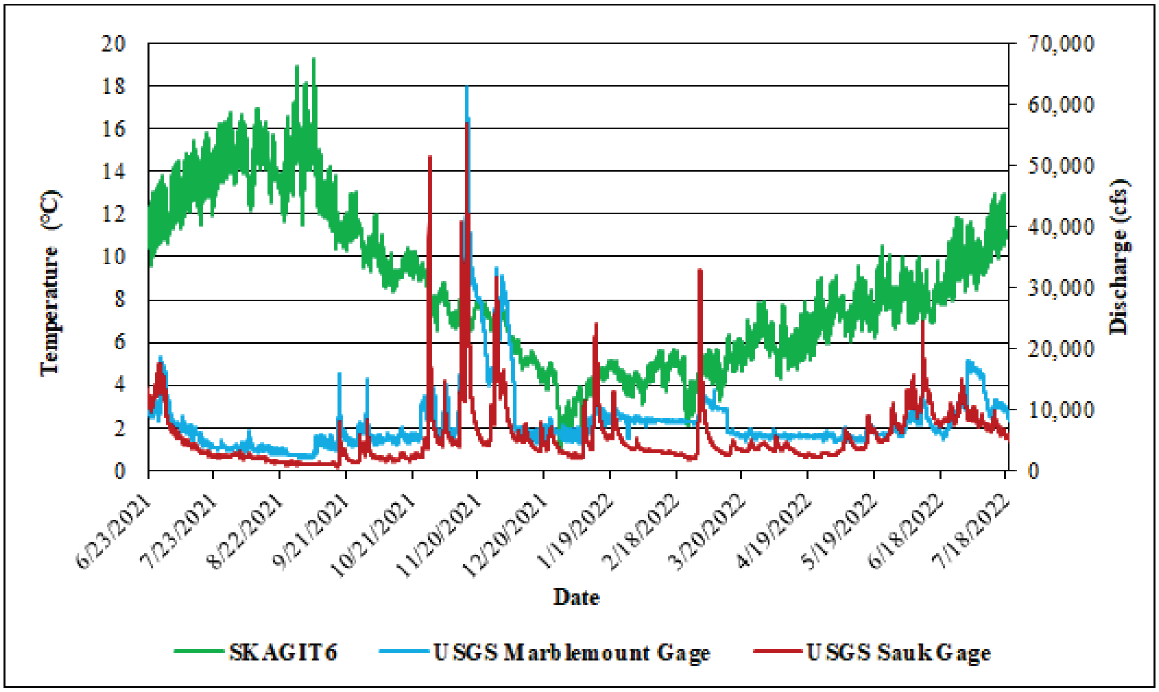



**Figure 5.3-4.** **30-minute water temperatures at SKAGIT6 (PRM 60.8) and Skagit River discharge as monitored at the USGS Marblemount gage (12181000) and Sauk River discharge as monitored at the USGS Sauk River gage (12189500) (June 23, 2021-July 18, 2022).**

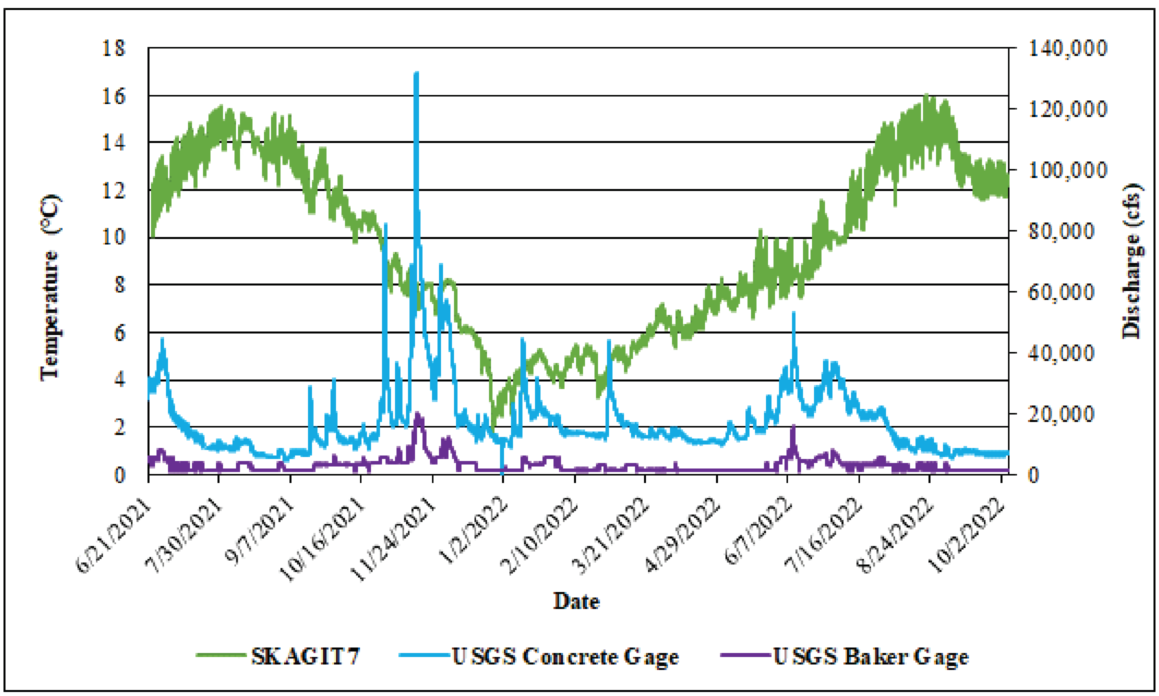
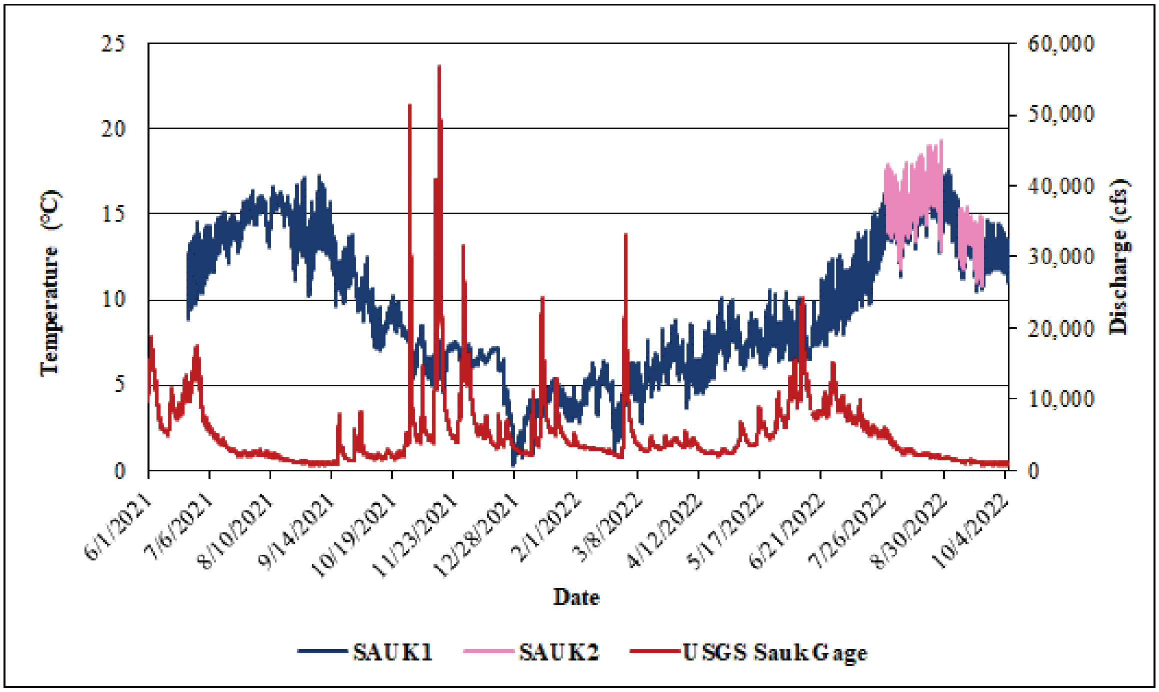
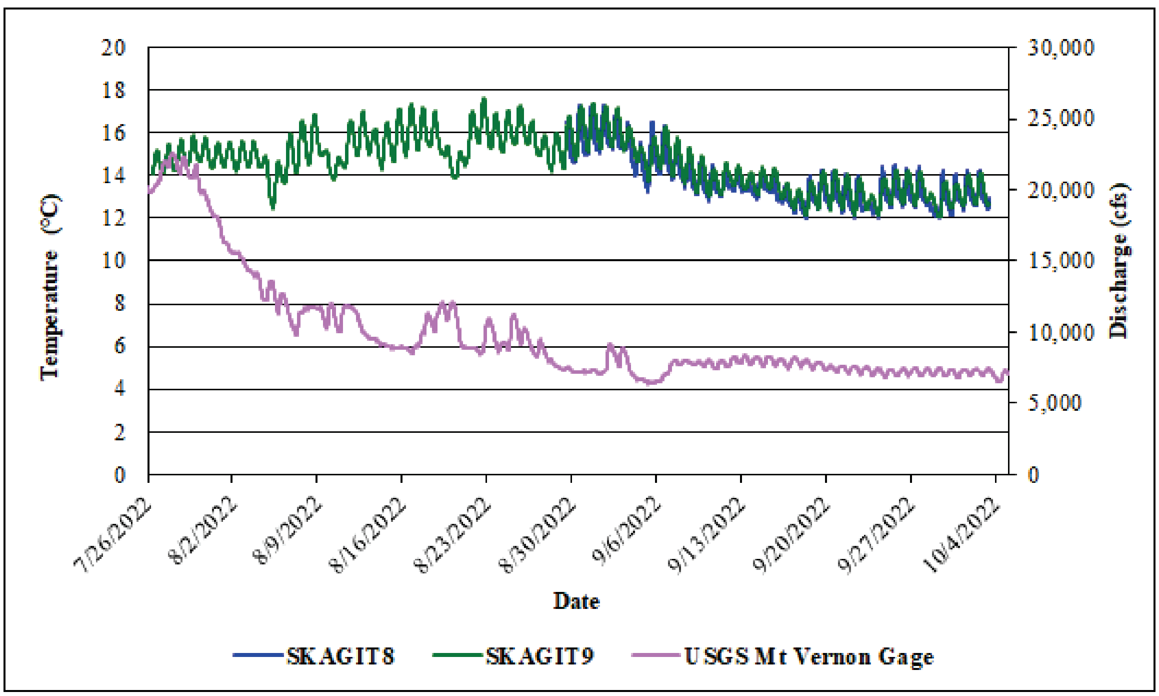



**Figure 5.3-5.** **30-minute water temperatures at SKAGIT7 (PRM 54.5) and Skagit River discharge as monitored at the USGS Concrete gage (12194000), and Baker River discharge as monitored at the USGS Baker River gage (12193400) (June 21, 2021-October 2, 2021).**



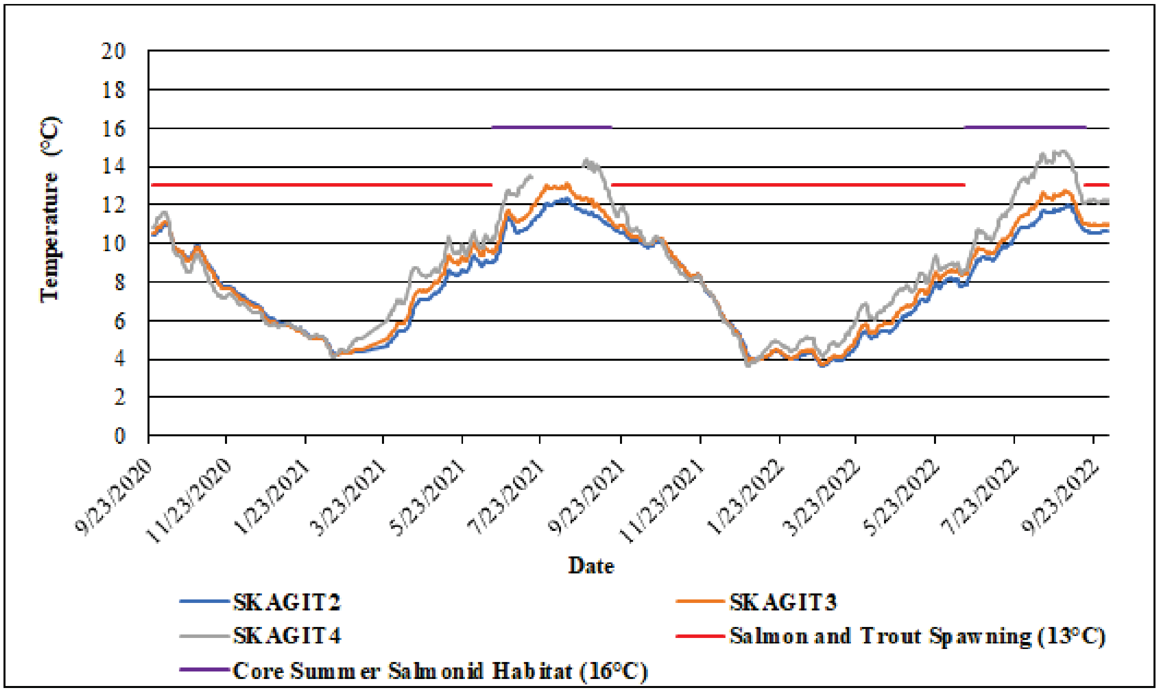

Note: SAUK2 was not deployed until July 2022 and was dewatered for short periods.

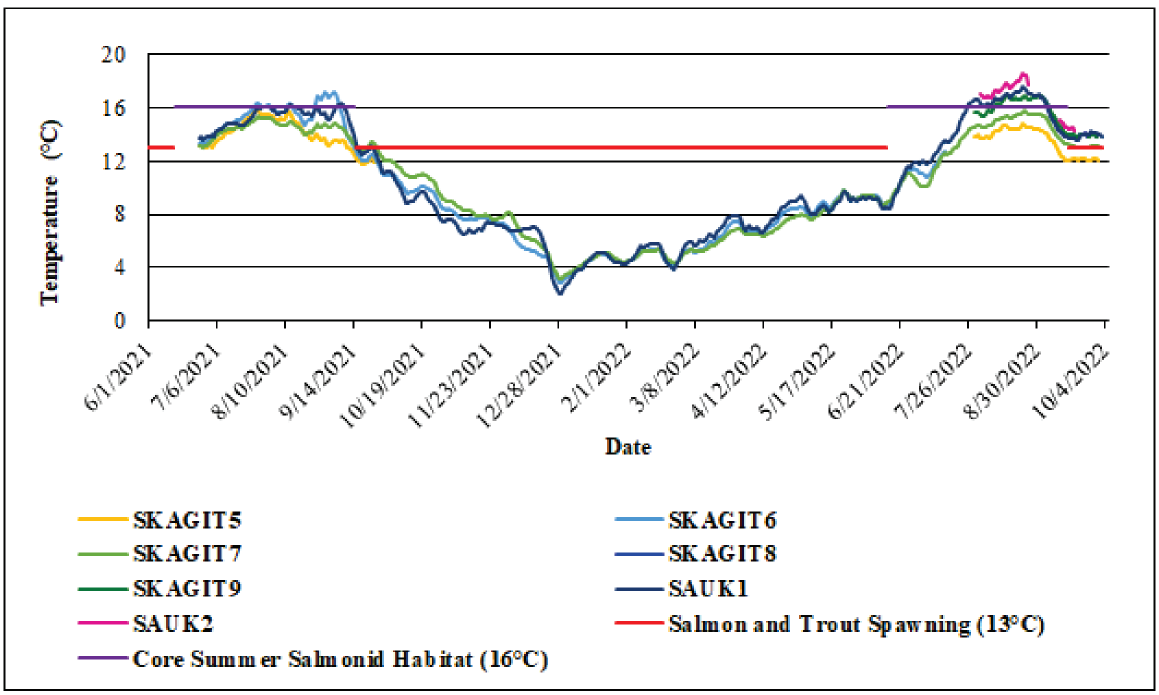
**Figure 5.3-6. 30-minute water temperatures at SAUK1 and 2 (RM 5.4 and 13.2) and discharge as monitored at the USGS Sauk gage (12189500) (June 1, 2021-October 4, 2022).**




Note: SKAGIT9 was not deployed until July 2022. SKAGIT8 was not deployed until September 2022.

**Figure 5.3-7. 30-minute water temperatures at SKAGIT8 and 9 (PRM 42.2 and 23.1) and discharge as monitored at the USGS Mount Vernon gage (12200500) (July 26 - October 4, 2022).**




Note: SKAGIT4 was dewatered from mid-July through mid-August 2021. SKAGIT5 was lost in winter 2021 due to high flows and replaced in July 2022. SKAGIT8-9 and SAUK2 were not deployed until July 2022. SKAGIT4 and SAUK2 were dewatered for short periods.

**Figure 5.3-8. 7-DADMax water temperatures at Skagit River sites upstream from Marblemount (SKAGIT2-4, top) (September 2020-September 2022), 7-DADMax water temperatures at Skagit River sites from Marblemount downstream to Concrete including the Sauk River site (SKAGIT5-9, SAUK1-2, bottom) (June 1, 2021-October 4, 2022). Horizontal lines show Ecology temperature standards.**

**Table 5.3-2. The highest 7-DADMax water temperature recorded at each lower Skagit River (SKAGIT2-9) and Sauk River (SAUK1-2) site during the 2020-2022 monitoring period.**

| Site ID | Location | Highest 7-DADMax Water Temperature Recorded (°C) | Date |
|---|---|---|---|
| SKAGIT2 | PRM 91.6 | 12.3 | 8/12/21 |
| SKAGIT3 | PRM 85.9 | 13.2 | 8/12/21 |
| SKAGIT4 | PRM 75.6 | 14.8 | 8/28/22 |
| SKAGIT5 | PRM 69.3 | 16.0 | 7/27/21 |
| SKAGIT6 | PRM 60.8 | 17.2 | 8/31/21 |
| SKAGIT7 | PRM 54.5 | 15.7 | 8/24/22 |
| SKAGIT8 | PRM 42.2 | 16.8 | 9/2/22 |
| SKAGIT9 | PRM 23.1 | 16.9 | 8/24/22 |
| SAUK1 | Sauk River USGS RM 5.4 | 17.6 | 8/23/22 |
| SAUK2 | Sauk River USGS RM 13.2 | 18.5 | 8/23/22 |

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 intermittent localized pooling caused by sediment deposition around the deployment site, common to the shoreline in this reach.

#### 5.3.1.2 Side Channel Temperatures

Onset temperature loggers (thermographs) were deployed at four side channel sites in the Skagit River downstream of Gorge Powerhouse and at one side channel site in the Sauk River. Site locations are shown in Figure 4.1-2 and listed in Table 4.1-1 (see map in Attachment A). Thermographs are generally deployed at a depth of around 1-m; however, stage fluctuations occasionally cause temperature variability.

Water temperatures at SKAGIT2SC and SKAGIT4SC are typically very close to those at their respective main channel sites (Figures 5.3-9 and 5.3-10). Both of these side channels remain wetted even under base flow conditions, and temperature patterns in the side channels were not correlated with flows at nearby USGS gages (Newhalem [12178000] or Marblemount [12181000]).

The side channel at SKAGIT6SC contains a higher proportion of the streamflow than the two upstream side channels. The SKAGIT6 thermograph malfunctioned in September 2022, and water temperatures cannot be compared between the main channel and side channel at this time (Figure 5.3-11). The failed thermograph has been replaced. Access to the SKAGIT8SC thermograph is via boat, and the site has not been accessible due to low river stage. Data collection in both the Skagit River and side channels is ongoing and will continue through May 2023.

Unlike the Skagit River main channel and side channel sites, the Sauk River main channel site had slightly warmer temperatures than the side channel during August and mid-September 2022 (Figure 5.3-12). This may be due to tributary or groundwater input in the side channel.

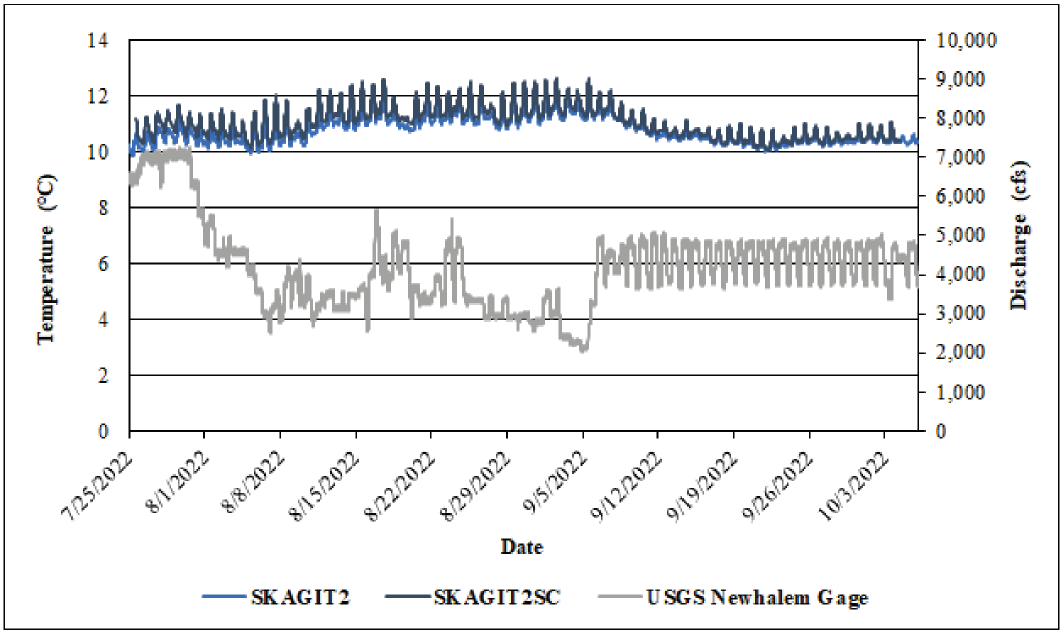



**Figure 5.3-9. 30-minute water temperatures at SKAGIT2 and SKAGIT2SC and discharge as monitored at the USGS Newhalem gage (12178000) (July 25-October 2022).**

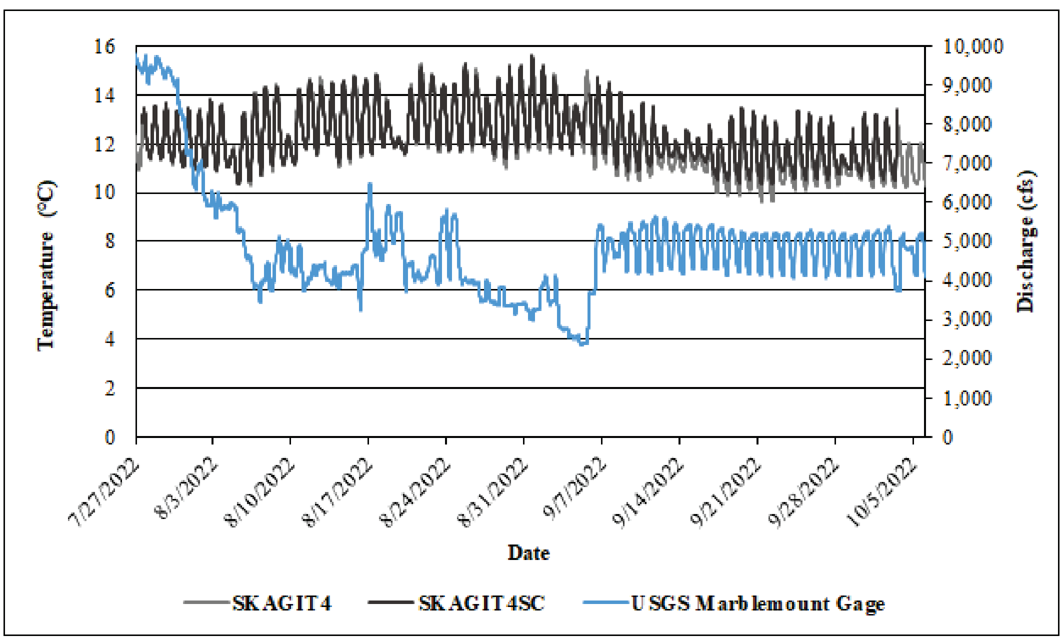
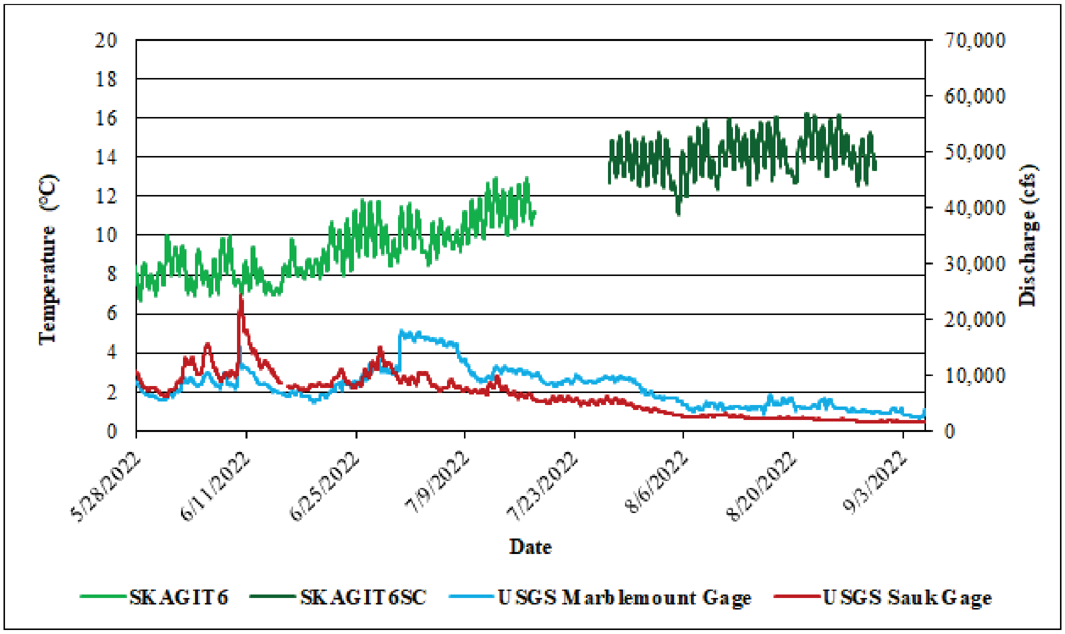
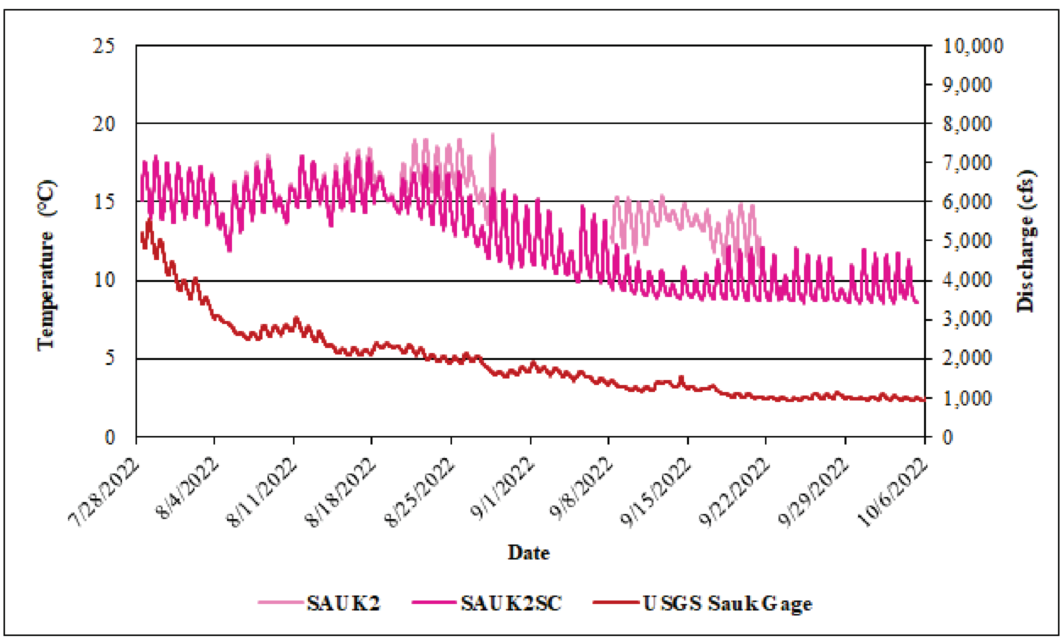



**Figure 5.3-10. 30-minute water temperatures at SKAGIT4 and SKAGIT4SC and discharge as monitored at the USGS Marblemount gage (12181000) (August-September 2022).**




Note: SKAGIT6 failed in mid-July and was replaced in September. SKAGIT6SC was not deployed until July 2022.

**Figure 5.3-11. 30-minute water temperatures at SKAGIT6 and SKAGIT6SC and discharge as monitored at the USGS Marblemount gage (12181000) and Sauk gage (12189500) (June-August 2022).**




Note: SAUK2 and SAUK2SC were not deployed until July 2022. SAUK2 was dewatered for short periods.

**Figure 5.3-12. 30-minute water temperatures at SAUK2 and SAUK2SC and discharge as monitored at the USGS Sauk River gage (12189500) (August-September, 2022).**

#### 5.3.1.3 Off-Channel Temperatures

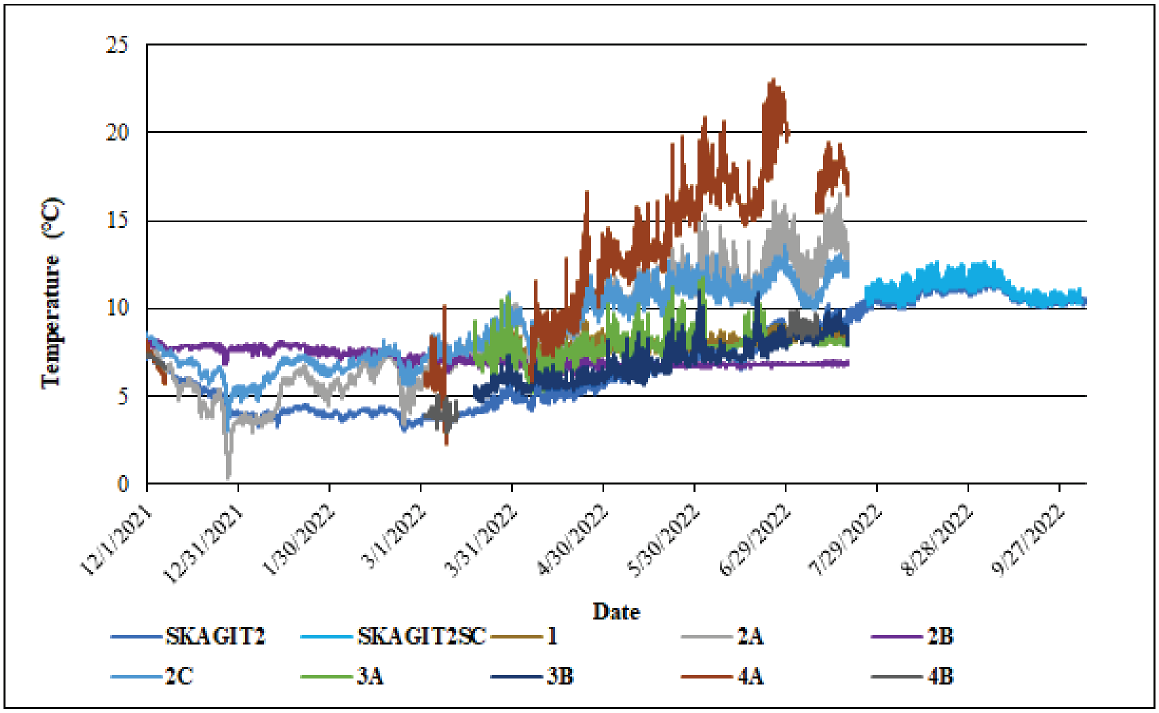
As specified in the June 9, 2021 Notice, continuous stage readers and temperature loggers were installed in the Skagit River floodplain to validate floodplain connectivity. Monitoring sites for this study are located within the Skagit River floodplain downstream of Newhalem and upstream of the Sauk River confluence. Site descriptions and the location of the nearest main channel thermograph are included in Table 5.3-3. For more detail on level-logger sites, see the GE-04 Skagit River Geomorphology between Gorge Dam and the Sauk River Study report (GE-04 Geomorphology Study; City Light 2023d).

**Table 5.3-3. Inventory of continuous stage readers and temperature loggers and nearest main channel thermograph location.**

| Site ID | Description | Date of Deployment | Nearest Main Channel Thermograph |
|---|---|---|---|
| 1 | Park Slough | 3/29/2022 | SKAGIT2 |
| 2A | Newhalem Agg Ponds -West | 11/30/2021 | SKAGIT2 |
| 2B | Channel draining to Newhalem Agg Ponds | 11/30/2021 | SKAGIT2 |
| 2C | Newhalem Agg Ponds – East | 11/30/2021 | SKAGIT2 |
| 3A | Thornton Side Channel Complex – Upper | 3/18/2022 | SKAGIT2 |
| 3B | Thornton Side Channel Complex – Lower | 3/18/2022 | SKAGIT2 |
| 4A | County Line Ponds – West | 11/29/2021 | SKAGIT2 |
| 4B | County Line Ponds – East | 11/29/2021 | SKAGIT2 |
| 20* | Pond near Damnation Creek | 5/20/2022 | SKAGIT2 |
| 5* | Pond across from Bacon Creek | 2/1/2022 | SKAGIT3 |
| 7* | Taylor Side Channel | 2/1/2022 | SKAGIT3 |
| 9 | Pressentin Park Side Channel | 12/14/2021 | SKAGIT4 |
| 12 | Pond near Pandora Circle | 12/14/2021 | SKAGIT4 |
| 13* | Floodplain Swale near Corkindale Ck | 5/20/2022 | SKAGIT4 |
| 14 | Illabot Ponds – East | 1/27/2022 | SKAGIT4 |
| 15 | Illabot Ponds – West | 2/24/2022 | SKAGIT4 |
| 16 | Illabot Slough | 2/24/2022 | SKAGIT4 |
| 18 | Washington Eddy | 4/20/2022 | SKAGIT4 |
| 17 | O'Brien Slough | 3/17/2022 | SKAGIT4 |
| 24 | Johnson Side Channel | 12/14/2021 | SKAGIT5 |

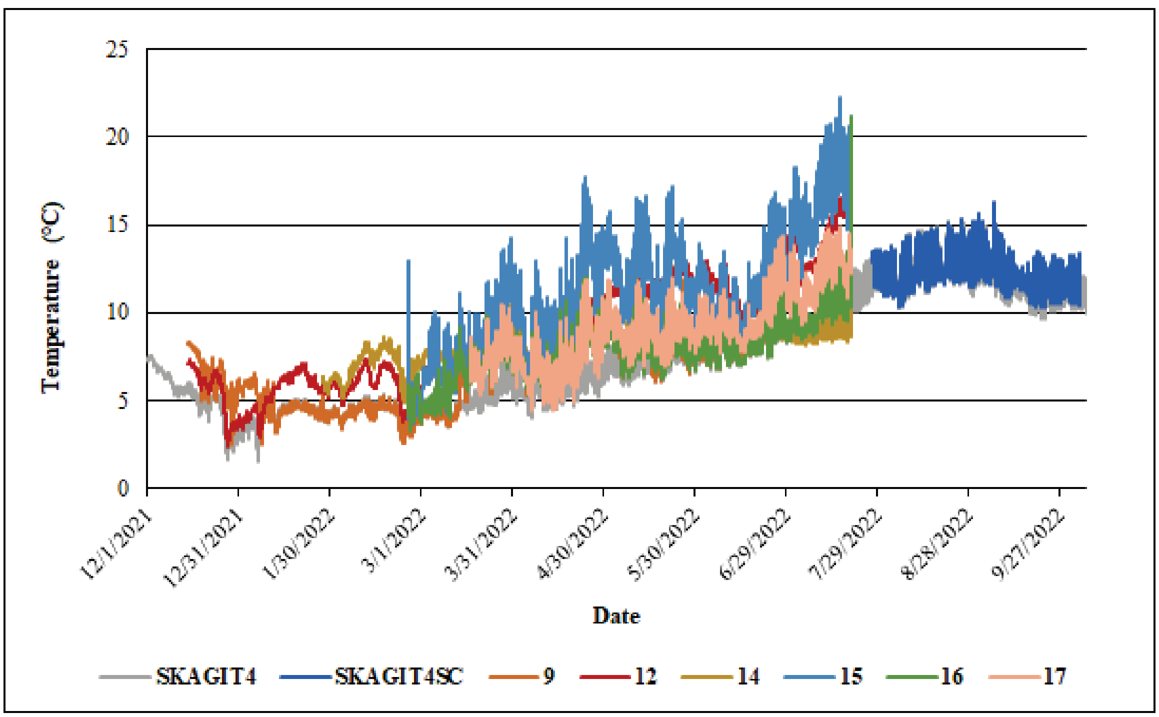
Note: A map of these locations can be found in the GE-04 Geomorphology Study (City Light 2023d).
*Data from off-channel site not available at the time of reporting.

Water temperatures in the off-channel areas near SKAGIT2 were similar to Skagit River temperatures in December 2021 but began to increase much more rapidly in the spring with the exception of the channel draining to the Newhalem Agg Ponds (Site 2B, Figure 5.3-13). This channel is a constructed, groundwater-fed channel that drains into the Agg Pond and remained stable in both stage (variation of only 0.4 ft) and temperature (range between 6.1°C and 8.1°C). Water temperatures in other off-channel areas reached as high as 23.0°C in late June 2022. Similarly, water temperatures in off-channel areas near Marblemount (SKAGIT4) and Rockport (SKAGIT5) were warmer than the mainstem Skagit River, with temperatures as high as 22.2°C at Illabot Ponds-West (Site 15) and 15.8°C at Washington Eddy (Site 18) in late-June (Figures 5.3-14 and 5.3-15). Data are only available for the off-channel temperature loggers through mid-July, but data collection at these sites is ongoing.



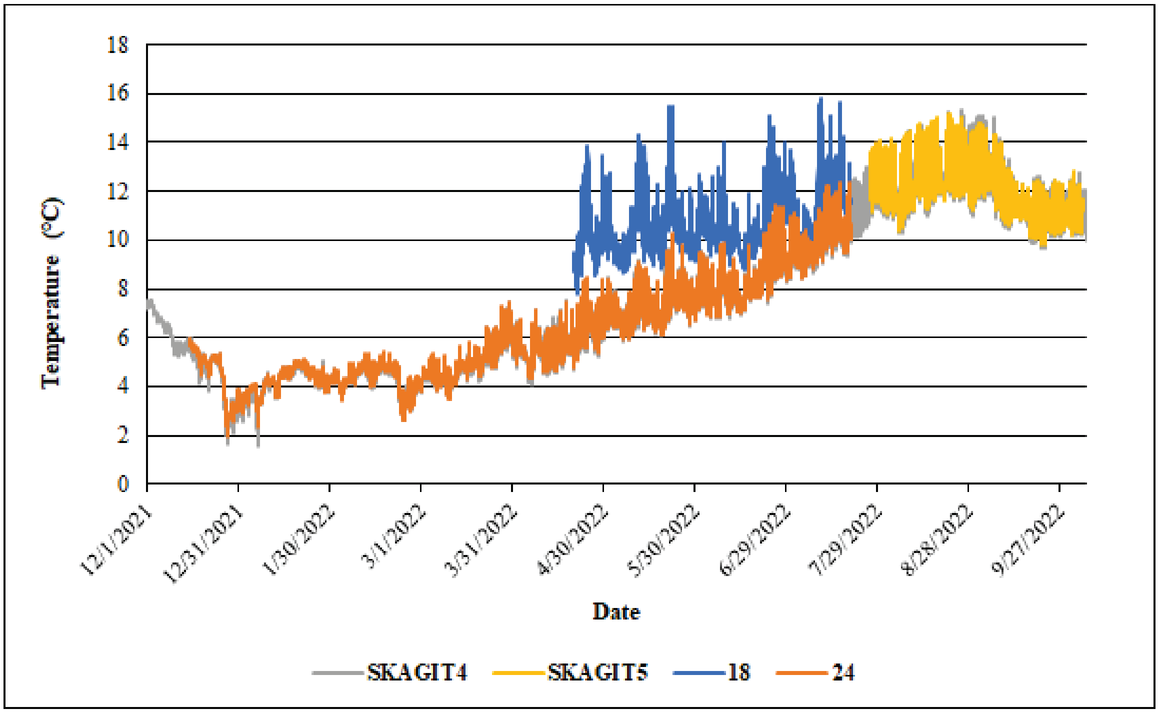

Note: SKAGIT2SC was not deployed until July 2022.

**Figure 5.3-13. 30-minute water temperatures at SKAGIT2 and SKAGIT2SC and eight closest off channel loggers (December 2021-September 2022).**




Note: SKAGIT4 was dewatered from mid-July through mid-August 2021. SKAGIT4SC was not deployed until July 2022.

**Figure 5.3-14. 30-minute water temperatures at SKAGIT4 and SKAGIT4SC and six closest off channel loggers (December 2021-September 2022).**




Note: SKAGIT4 was dewatered from mid-July through mid-August 2021. SKAGIT5 was lost in winter 2021 due to high flows and replaced in July 2022.

**Figure 5.3-15. 30-minute water temperatures at SKAGIT4, SKAGIT4SC, and SKAGIT5 and two closest off channel loggers (December 2021-September 2022).**

#### 5.3.1.4 Short-Term Continuous Temperature Monitoring

In support of development and calibration of the CE-QUAL-W2 water quality model (FA-01b WQ Model Development Study, City Light 2023a), sondes were deployed to continuously monitor water temperature, DO (concentration and saturation), turbidity, pH, and specific conductance at three locations in the lower Skagit River for three approximately two- to three-week-long periods. Sondes were deployed at SKAGIT3 (PRM 85.9), SKAGIT4 (PRM 75.6), and SKAGIT7 (PRM 54.5). Deployment dates were June 2 through 24, 2022; July 14 through August 4. 2022, and August 25 through September 8, 2022. Data were recorded at 30-minute intervals during each event. Time series plots for temperature during each of the three periods are presented below.

Temperatures at the three sites were cooler in June and ranged from 8.0°C at SKAGIT3 to 9.1°C at SKAGIT4. Diel changes were smaller at SKAGIT3. Differences among sites were largest in July; mean temperatures at SKAGIT7 were approximately 14°C and approximately 10.5°C at SKAGIT3. Time series and box and whisker plots of temperatures are shown in Figures 5.3-16 and 5.3-17, respectively.

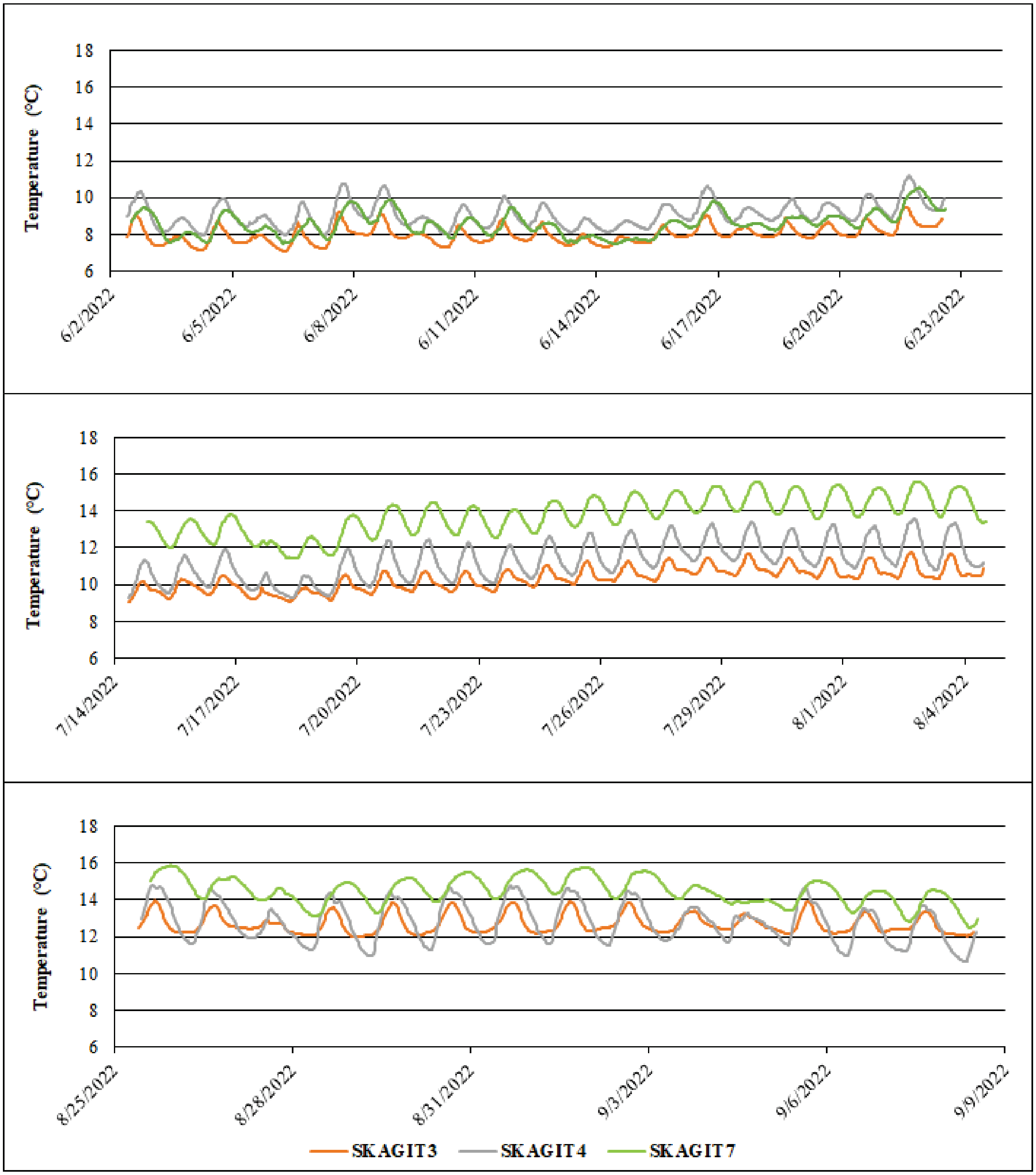



**Figure 5.3-16. Time series of temperatures at SKAGIT3, SKAGIT4, and SKAGIT7 in June (top), July-August (middle), and August-September (bottom) (2022).**

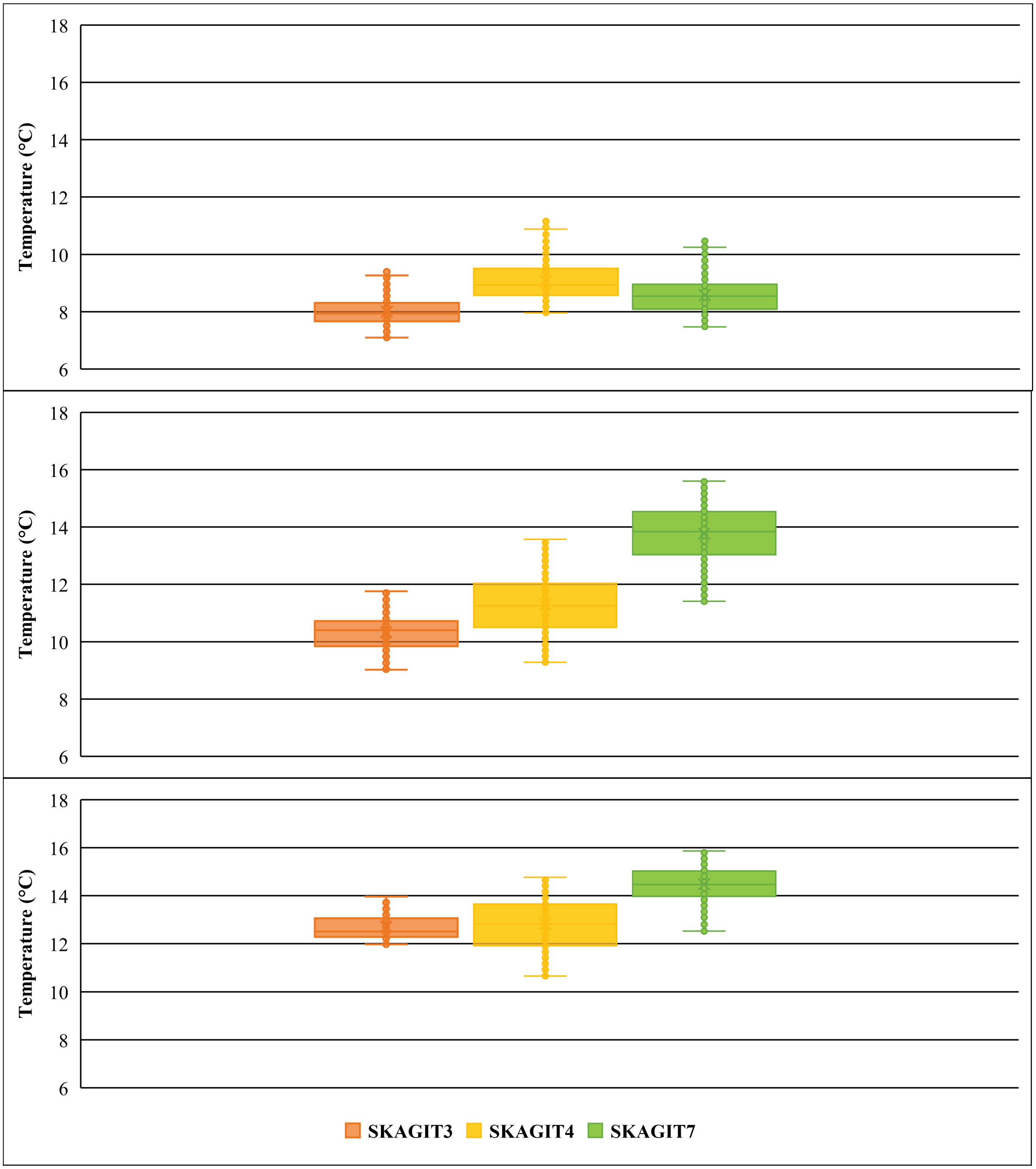



**Figure 5.3-17. Box-and-whisker plot of temperatures at SKAGIT3, SKAGIT4, and SKAGIT7 during continuous monitoring in June (top), July-August (middle), and August-September (bottom) (2022).**

#### 5.3.1.5 Instantaneous Temperature Measurements

Instantaneous water quality measurements were made monthly at four Skagit River mainstem sites (SKAGIT3, 4, 5, and 7) and four tributary sites (Newhalem Creek, Cascade River, Sauk River, and Baker River) (see Attachment A for site locations). Temperature, DO, specific conductance, and pH were measured with a sonde while grab samples were collected in the field for laboratory analysis for all other parameters. Temperature measurements at grab sample sites for May through September 2022 are shown in Table 5.3-4. Results for remaining parameters for turbidity, nutrients, chlorophyll *a*, carbon, and alkalinity are subsequently shown in their respective sections.

**Table 5.3-4. Instantaneous temperature measurement taken by sonde during grab sampling at Skagit River and tributary sites (May-September 2022).**

| Date | Temperature (°C) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | NEWCK | SKAGIT3 | CASC1 | SKAGIT4 | SKAGIT5 | SAUK1 | BAKER1 | SKAGIT7 |
| May 17, 2022 | 5.37 | 6.73 | 6.14 | 6.71 | 6.73 | 6.98 | 8.98 | 7.41 |
| Jun 16, 2022 | 7.84 | 6.99 | 7.9 | 7.55 | 7.28 | 9.65 | 9.99 | 9.43 |
| Jul 6, 2022 | 8.94 | 9.04 | 9.14 | 9.65 | 9.8 | 11.3 | 11.11 | 10.66 |
| Aug 3, 2022 | 11.43 | 11.28 | 11.76 | 12.27 | 12.31 | 14.95 | 13.7 | 14.05 |
| Sep 22, 2022 | 9.18 | 10.18 | 10.15 | 11.28 | 10.64 | 12.64 | 16.33 | 12.26 |

Notes: NEWCK = Newhalem Creek below bridge near Rock Shelter Trail; SKAGIT3 = road mile 113; CASC1 = Cascade River at Wagon Wheel Campground; SKAGIT4 = Glacier Peak; SKAGIT5 = Howard Miller Steelhead Park; SAUK1 = USGS Sauk River gage; BAKER1 = Baker River at WDFW access site; SKAGIT7 = Concrete.

### 5.3.2 Dissolved Oxygen

DO concentrations and saturations was continuously monitored from June 2 through 24, 2022; July 14 through August 4, 2022; and August 25 through September 8, 2022. DO concentrations at SKAGIT3 (PRM 85.9), SKAGIT4 (PRM 75.6), and SKAGIT7 (PRM 54.5) ranged from approximately 11 to 13 mg/L over the three monitoring periods (Figures 5.3-18 and 5.3-19), with saturation generally between 100 and 105 percent (Figures 5.3-20 and 5.3-21). Little diel fluctuation occurred in June at any of the three sites. Similar to the pattern observed for temperature, DO concentrations at SKAGIT3 exhibited a tighter range, between about 12.0 and 12.6 mg/L, than the other two sites. Maximum DO concentrations generally occurred during the afternoon, and daily maximum percent saturation was highest at SKAGIT4, up to 115 percent in August-September, suggesting an influence of primary production. The diel pattern at SKAGIT7 differed from the other sites: values were generally highest in the evening or at night, possibly due to tributary influences, including flows from the Baker River.

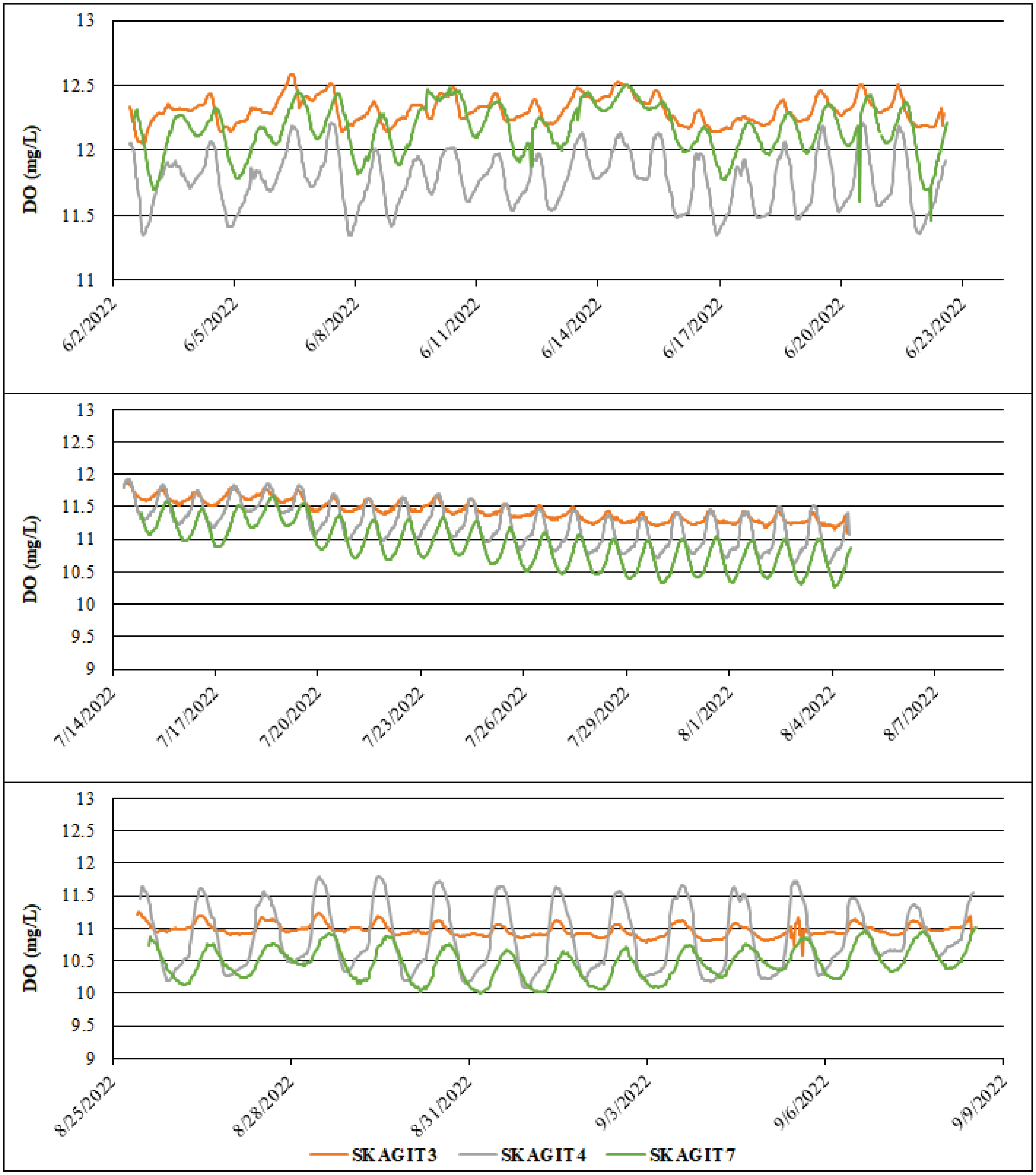



**Figure 5.3-18.** **Time series plot of DO concentrations at SKAGIT3, SKAGIT4, and SKAGIT7 during short-term continuous monitoring in June (top), July-August (middle), and August-September (bottom) (2022).**

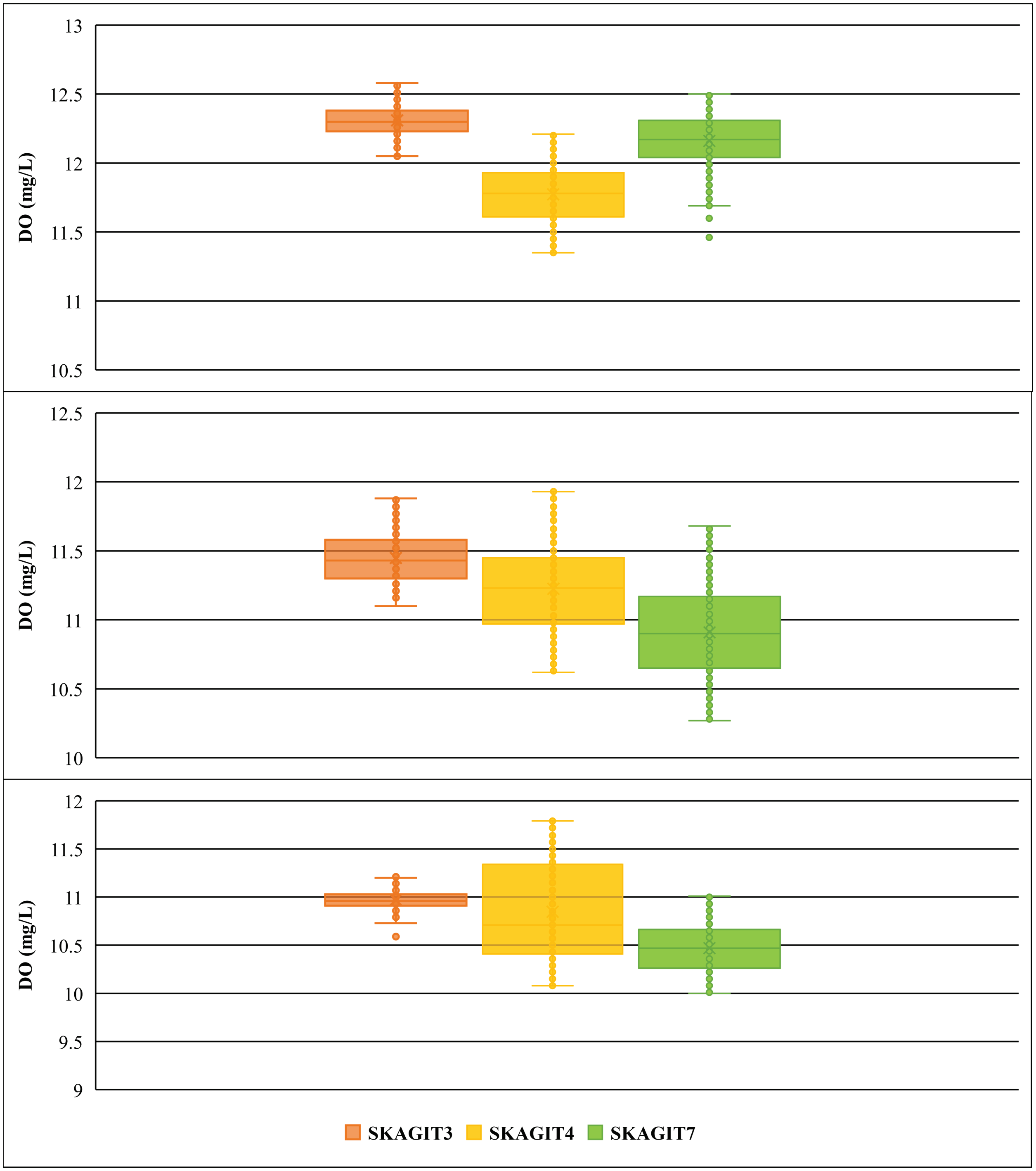



**Figure 5.3-19. Box-and-whisker plot of DO concentrations at SKAGIT3, SKAGIT4, and SKAGIT7 during short-term continuous monitoring in June (top), July-August (middle), and August-September (bottom) (2022).**

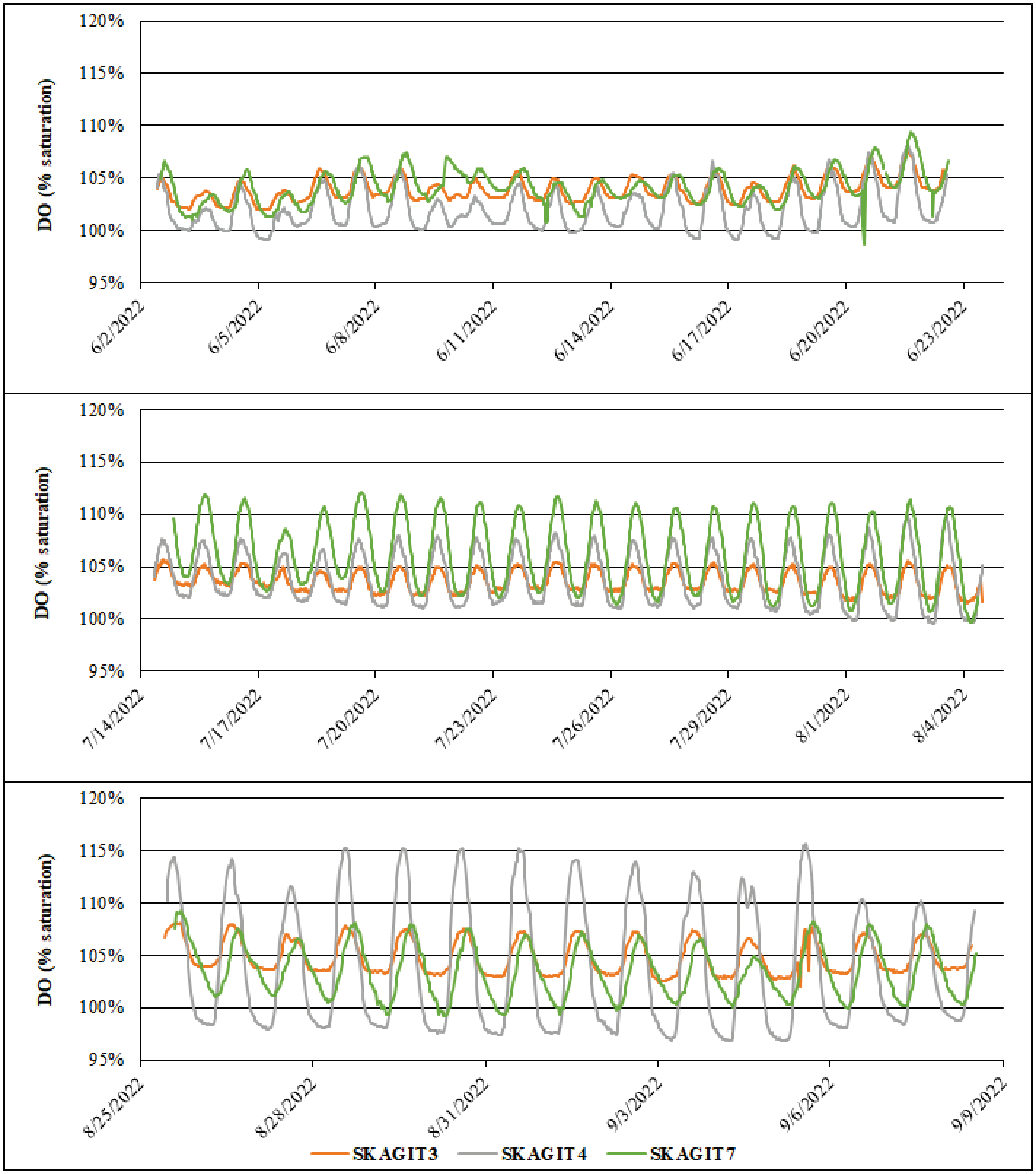



**Figure 5.3-20.** **Time series plot of DO percent saturation at SKAGIT3, SKAGIT4, and SKAGIT7 during short-term continuous monitoring in June (top), July-August (middle), and August-September (bottom) (2022).**

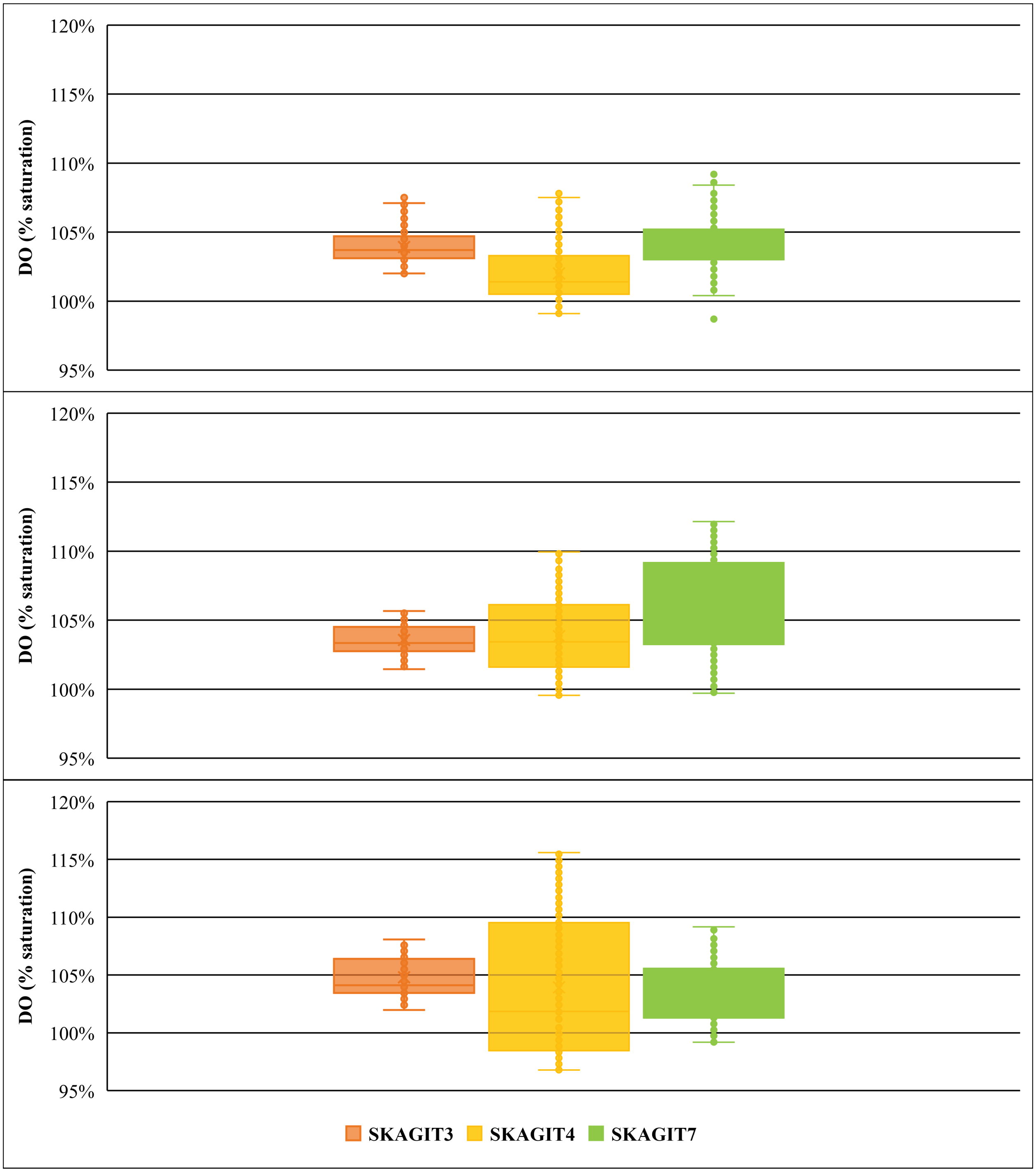



**Figure 5.3-21. Box and whisker plot of DO percent saturation at SKAGIT3, SKAGIT4, and SKAGIT7 during short-term continuous monitoring in June (top), July-August (middle), and August-September (bottom) (2022).**

DO concentration was also recorded during instantaneous water quality monitoring with a sonde at four Skagit River mainstem sites (SKAGIT3, 4, 5, and 7) and four tributary sites (Newhalem Creek, Cascade River, Sauk River, and Baker River) (see Attachment A for site locations). DO concentration results are shown below for samples collected from May through September 2022 (Table 5.3-5).

The DO concentrations at the mainstem sites ranged from approximately 10.8 to 12.5 mg/L while DO concentrations at the tributary sites were generally slightly lower ranging from approximately 10.3 to 12.3 mg/L.

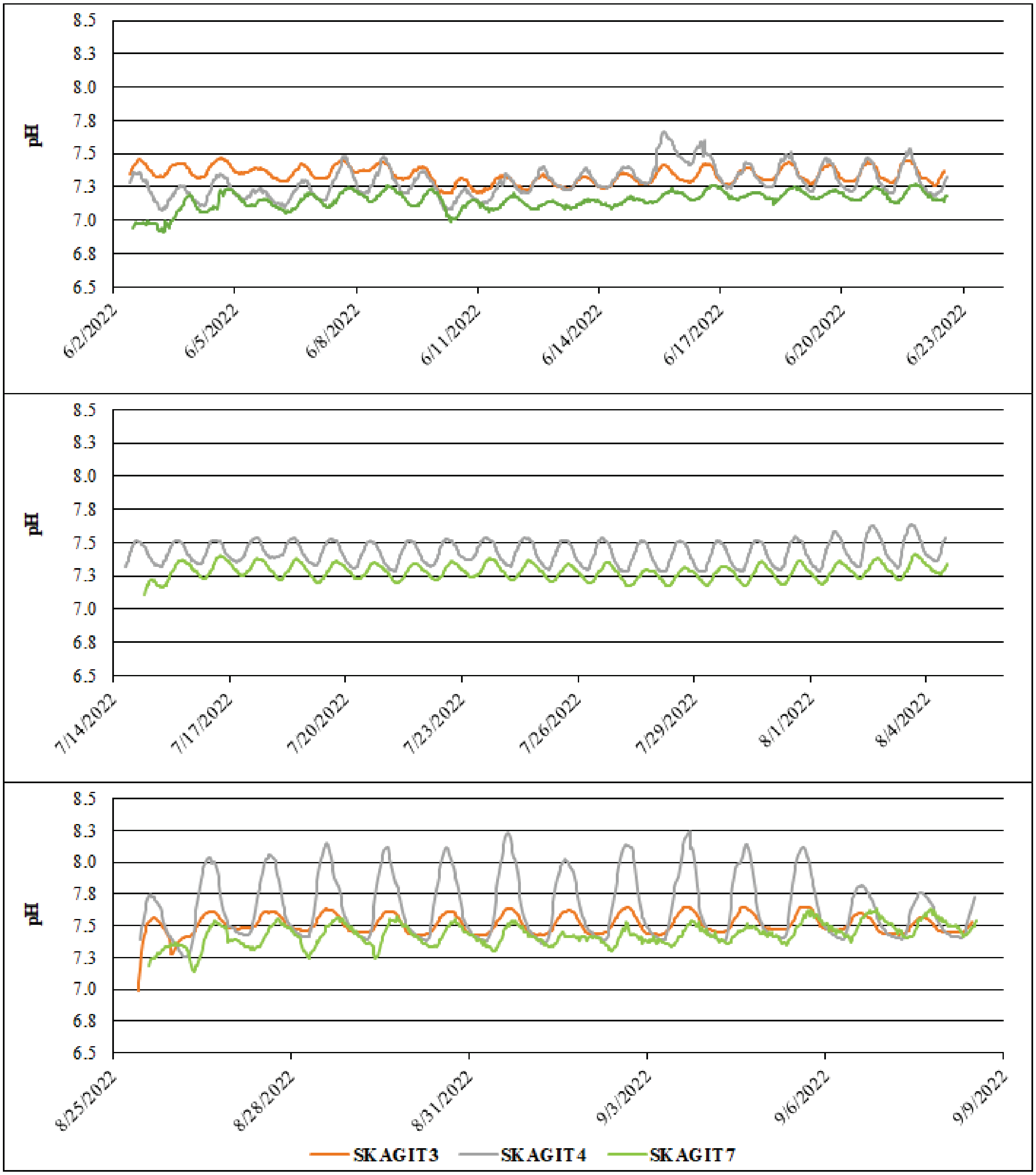
**Table 5.3-5. Instantaneous DO measurement collected by multiparameter sonde during grab sampling at Skagit River and tributary sites (May-September 2022).**

| | DO (mg/L) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Date** | **NEWCK** | **SKAGIT3** | **CASC1** | **SKAGIT4** | **SKAGIT5** | **SAUK1** | **BAKER1** | **SKAGIT7** |
| May 17, 2022 | 12.27 | 12.01 | 11.85 | 12.1 | 11.94 | 11.97 | 11.69 | 11.76 |
| Jun 16, 2022 | 11.97 | 12.47 | 11.89 | 12.28 | 12.12 | 11.6 | 12.11 | 11.79 |
| Jul 6, 2022 | 11.94 | 12.34 | 11.88 | 12.06 | 11.97 | 11.39 | 12.11 | 11.76 |
| Aug 3, 2022 | 11.08 | 11.32 | 11.1 | 11.65 | 11.29 | 10.59 | 11.27 | 11.09 |
| Sep 22, 2022 | 11.19 | 10.91 | 11.03 | 11.2 | 10.86 | 10.94 | 10.31 | 10.8 |

NEWCK = Newhalem Creek below bridge near Rock Shelter Trail; SKAGIT3 = road mile 113; CASC1 = Cascade River at Wagon Wheel Campground; SKAGIT4 = Glacier Peak; SKAGIT5 = Howard Miller Steelhead Park; SAUK1 = USGS Sauk River gage; BAKER1 = Baker River at WDFW access site; SKAGIT7 = Concrete.

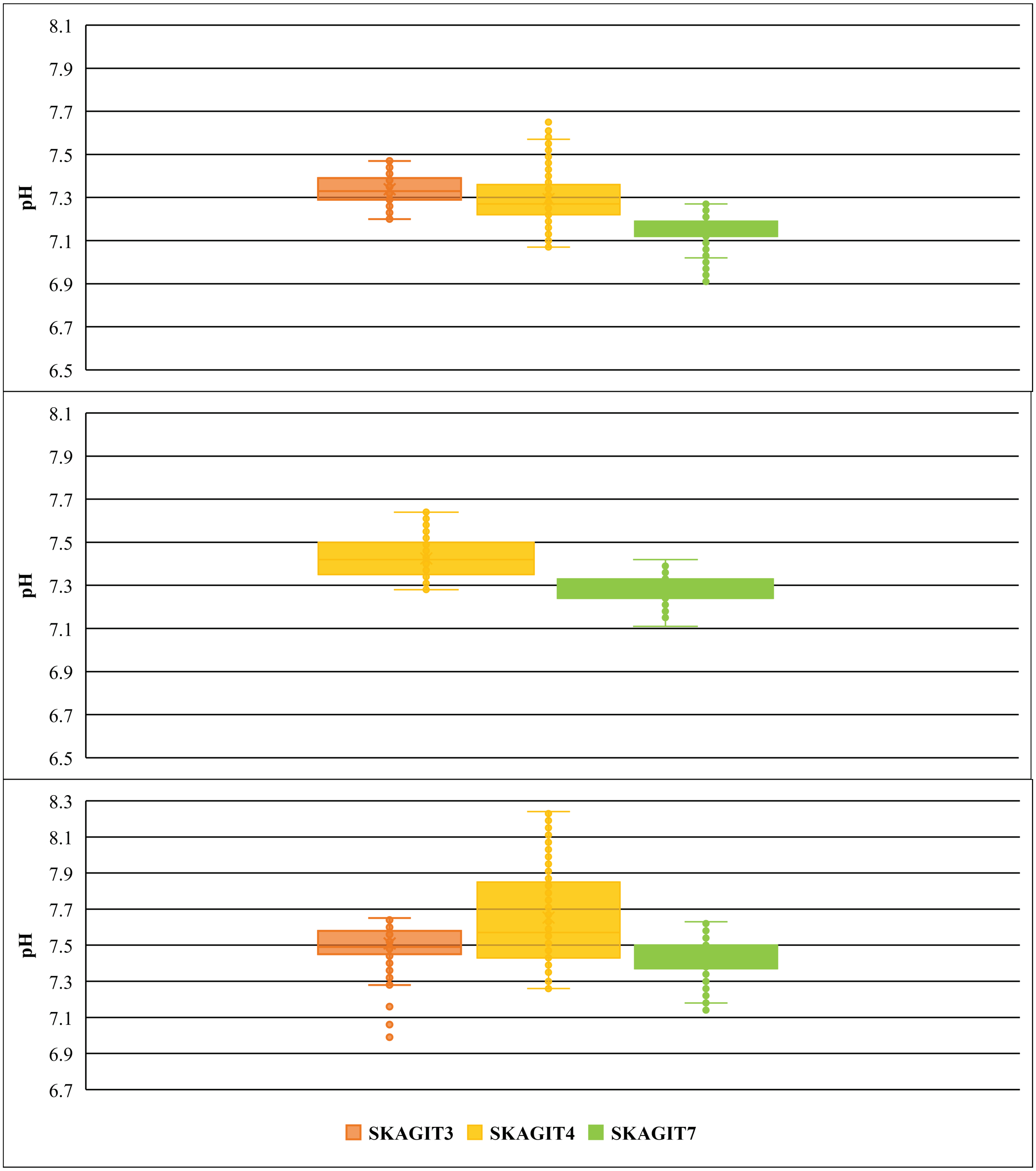
### 5.3.3 pH

The continuously monitored pH values at SKAGIT3 (PRM 85.9), SKAGIT4 (PRM 75.6), and SKAGIT7 (PRM 54.5) were relatively constant in June and July-August, generally between 7.0 and 7.5, with diel changes of 0.25 to 0.5 pH units (Figures 5.3-22 and 5.3-23). A similar range was observed in August-September at SKAGIT3 and SKAGIT7. However, pH at SKAGIT4 was markedly higher, reaching 8.3, with maximum diel changes of almost a full pH unit. August-September data suggest an effect due to primary production, during which photosynthetic uptake of $CO_2$ raises pH; this pattern is consistent with DO data described above that show oxygen evolution during daylight hours. The sonde deployed at SKAGIT3 in July experienced a multi-sensor failure, and pH values were not recorded during this deployment.




Note: The sonde deployed at SKAGIT3 in July experienced a multi-sensor failure and pH values were not recorded during this deployment.

**Figure 5.3-22. Time series plot of pH at SKAGIT3, SKAGIT4, and SKAGIT7 during short-term continuous monitoring in June (top), July-August (middle), and August-September (bottom) (2022).**




Note: The sonde deployed at SKAGIT3 in July experienced a multi-sensor failure and pH values were not recorded during this deployment.

**Figure 5.3-23. Box-and-whisker plot of pH at SKAGIT3, SKAGIT4, and SKAGIT7 during short-term continuous monitoring in June (top), July-August (middle), and August-September (bottom) (2022).**

PH values were also measured during instantaneous water quality monitoring with a sonde during grab sampling from May through September 2022 (Table 5.3-6). Recorded pH values at mainstem Skagit River sites were between approximately 6.4 and 7.1 units, while pH values in Skagit River tributaries downstream of the Project showed slightly more variance, generally between 6.2 and 7.3 units.

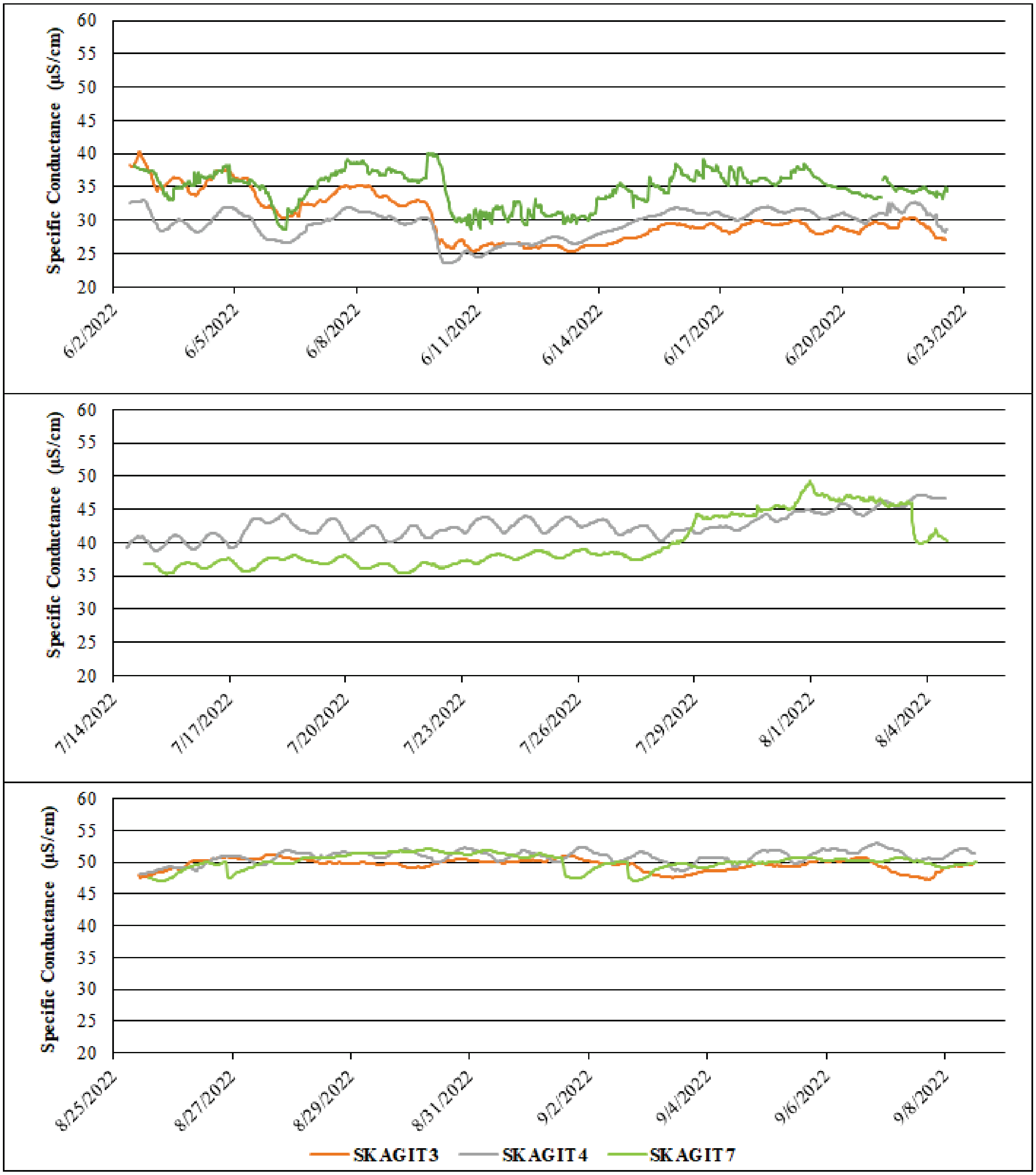
**Table 5.3-6. Instantaneous pH measurement recorded by multiparameter sonde during grab sampling at Skagit River and tributary sites (May- September 2022).**

| Date | pH (unit) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | NEWCK | SKAGIT3 | CASC1 | SKAGIT4 | SKAGIT5 | SAUK1 | BAKER1 | SKAGIT7 |
| May 17, 2022 | 7.25 | 6.94 | 7.25 | 7.12 | 7.08 | 7.12 | 7.07 | 7.13 |
| Jun 16, 2022 | 6.44 | 6.97 | 6.5 | 6.74 | 6.92 | 6.74 | 6.58 | 6.66 |
| Jul 6, 2022 | 6.66 | 6.83 | 6.92 | 6.94 | 6.89 | 6.9 | 6.91 | 6.85 |
| Aug 3, 2022 | 6.34 | 6.42 | 6.43 | 6.57 | 6.42 | 6.64 | 6.21 | 6.5 |
| Sep 22, 2022 | 6.55 | 6.7 | 6.86 | 6.99 | 6.83 | 7.24 | 6.72 | 6.91 |

NEWCK = Newhalem Creek below bridge near Rock Shelter Trail; SKAGIT3 = road mile 113; CASC1 = Cascade River at Wagon Wheel Campground; SKAGIT4 = Glacier Peak; SKAGIT5 = Howard Miller Steelhead Park; SAUK1 = USGS Sauk River gage; BAKER1 = Baker River at WDFW access site; SKAGIT7 = Concrete.

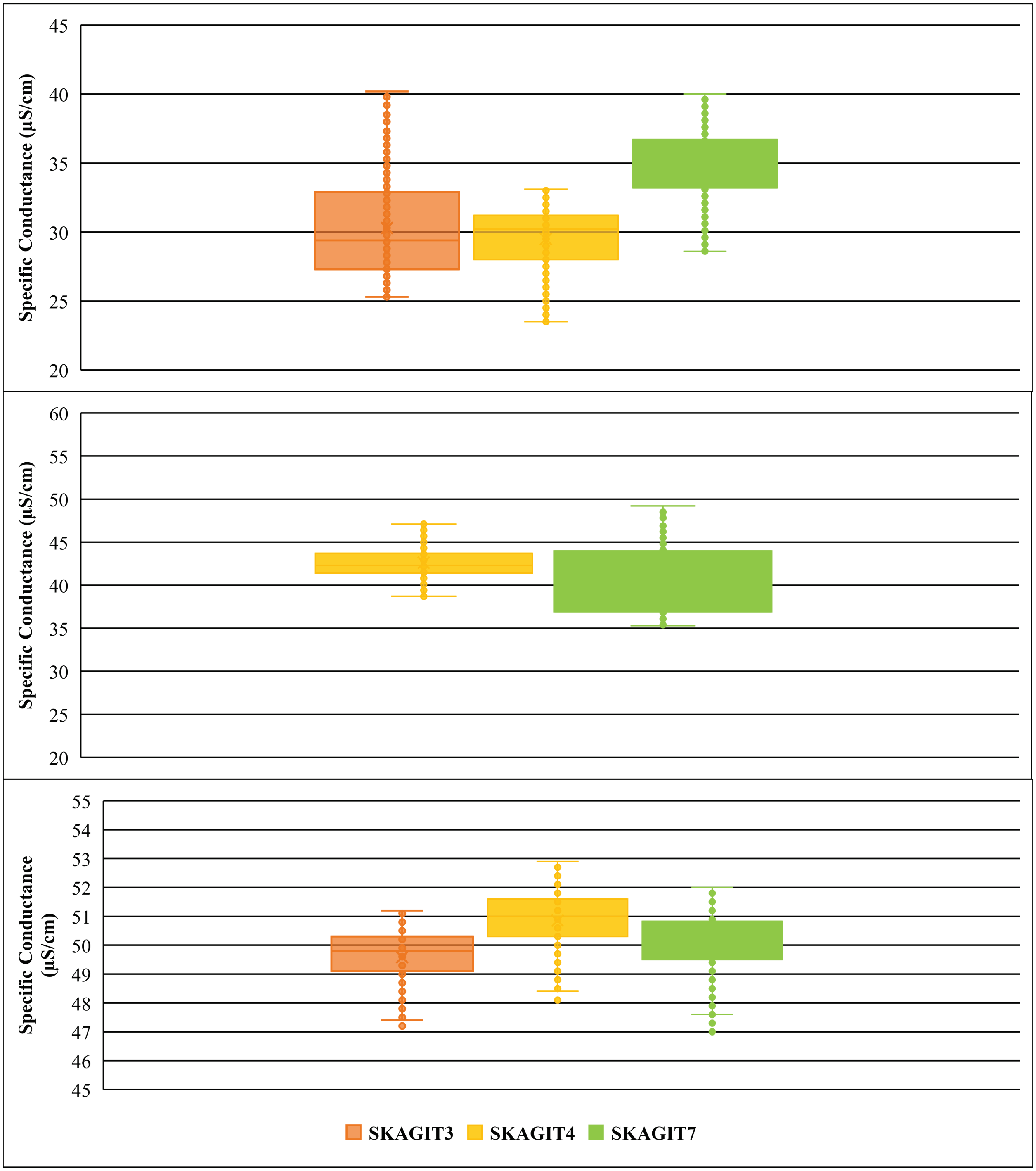
### 5.3.4 Specific Conductance

During the three continuous monitoring periods at SKAGIT3 (PRM 85.9), SKAGIT4 (PRM 75.6), and SKAGIT7 (PRM 54.5), specific conductance ranged from approximately 25-35 microsiemens per centimeter (µS/cm) in June at the three sites, increasing in August with higher water temperatures, and with less of a range among sites (approximately 48-52 µS/cm) (Figures 5.3-24 and 5.3-25).




Note: The sonde deployed at SKAGIT3 in July experienced a multi-sensor failure and pH values were not recorded during this deployment.

**Figure 5.3-24. Time series plot of specific conductance at SKAGIT3, SKAGIT4, and SKAGIT7 during continuous monitoring in June (top), July-August (middle), and August-September (bottom) (2022).**




Note: The sonde deployed at SKAGIT3 in July experienced a multi-sensor failure and pH values were not recorded during this deployment.

**Figure 5.3-25. Box-and-whisker plot of specific conductance at SKAGIT3, SKAGIT4, and SKAGIT7 during continuous monitoring in June (top), July-August (middle), and August-September (bottom) (2022).**

Monthly specific conductance values varied depending on sampling site (Table 5.3-7). Specific conductance at the mainstem Skagit River sites and larger tributaries, including the Baker and Sauk rivers were between 25-68 µS/cm. The smaller Skagit River tributaries showed the greatest variance among sites, most notably Newhalem Creek consistently measured low specific conductance values between 12-25 µS/cm. The overall low specific conductance values across all sites, consistent with data in Figures 5.3-24 and 5.3-25, reflect low dissolved ions.

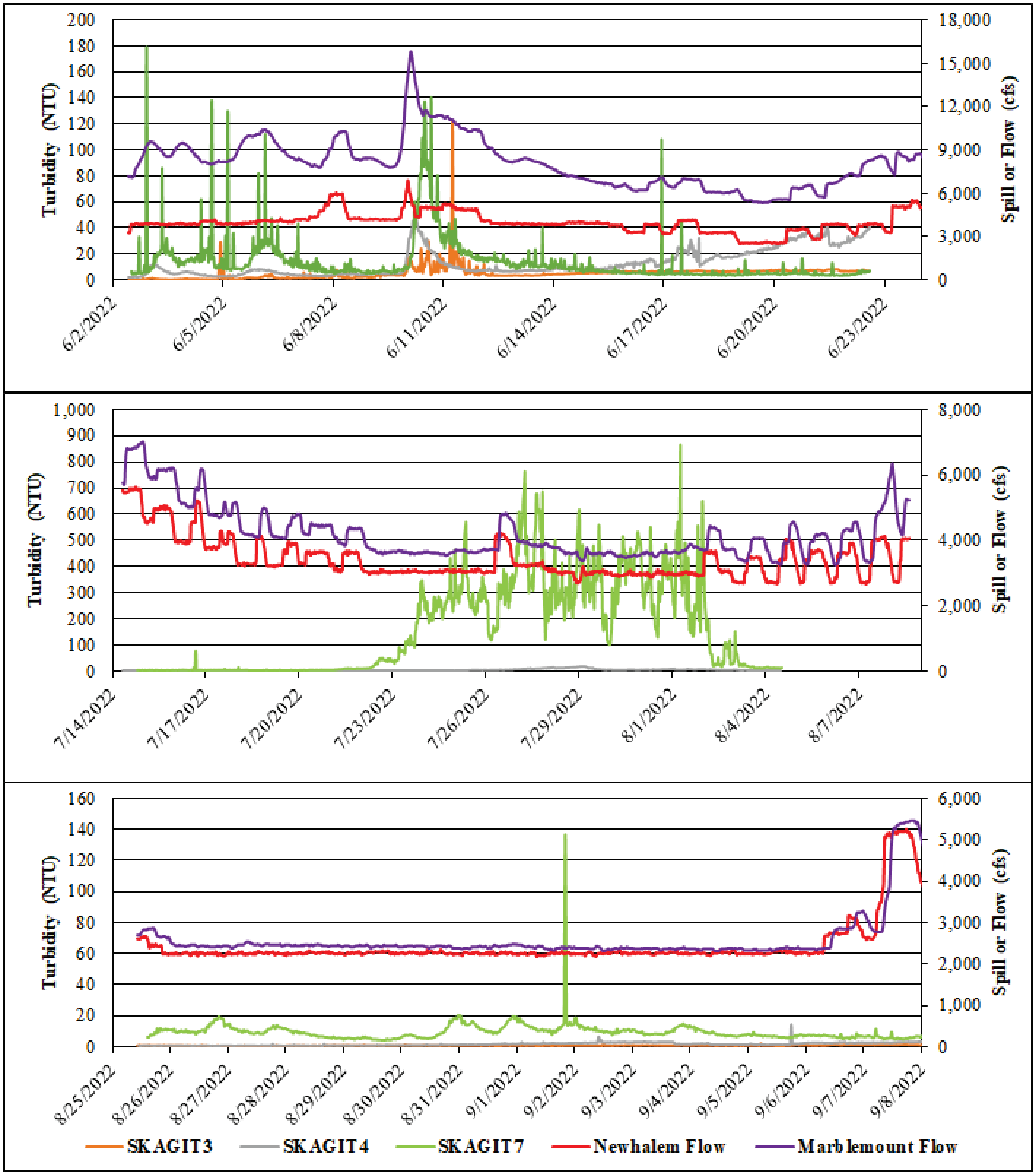
**Table 5.3-7. Instantaneous specific conductance measurement recorded by multiparameter sonde during grab sampling at Skagit River and tributary sites (May-September 2022).**

| Date | Specific Conductance (µS/cm) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | NEWCK | SKAGIT3 | CASC1 | SKAGIT4 | SKAGIT5 | SAUK1 | BAKER1 | SKAGIT7 |
| May 17, 2022 | 16 | 48 | 34 | 42 | 44 | 38 | 55 | 43 |
| Jun 16, 2022 | 14 | 25 | 32 | 30 | 30 | 35 | 42 | 37 |
| Jul 6, 2022 | 12 | 44 | 26 | 40 | 41 | 30 | 36 | 37 |
| Aug 3, 2022 | 16 | 45 | 30 | 43 | 43 | 37 | 34 | 40 |
| Sep 22, 2022 | 25 | 58 | 45 | 57 | 57 | 68 | 42 | 57 |

SKAGIT3 = road mile 113; SKAGIT4 = Glacier Peak; SKAGIT5 = Howard Miller Steelhead Park; SKAGIT7 = Concrete. NEWCG = Newhalem Creek below bridge near Rock Shelter Trail; CASC1 = Cascade River at Wagon Wheel Campground; SAUK1 = USGS Sauk River gage; BAKER1 = Baker River at WDFW access site.

### 5.3.5 Turbidity

Turbidity was continuously monitored from June 2 through 24, 2022; July 14 through August 4, 2022; and August 25 through September 8, 2022 at SKAGIT3 (PRM 85.9), SKAGIT4 (PRM 75.6), and SKAGIT7 (PRM 54.5). The sonde deployed at SKAGIT3 in July experienced a multi-sensor failure and only temperature and DO data were recorded during this deployment. Baseline turbidity at the three monitoring sites was low (0-20 NTUs) during periods apparently unaffected by changes in Skagit River flows. However, spikes in turbidity were common at all three sites, reaching over 100 NTUs in June 2022 and 800-900 NTUs during late July/early August 2022 (Figure 5.3-26). Spill at Gorge Dam was not a factor during any of the three monitoring periods, with only a few short-term events of less than 1,000 cfs occurring on June 6, 2022. There is also little apparent relationship between Skagit River flow variability and turbidity spikes, except on June 10-11, 2022, when a spike in turbidity follows a high flow event. Turbidity spikes, such as the one measured on September 1 at SKAGIT7 (137 NTU), were generally of short duration and likely due to debris temporarily interfering with or blocking the turbidity sensor.




Note: The sonde deployed at SKAGIT3 in July experienced a multi-sensor failure and pH values were not recorded during this deployment.

**Figure 5.3-26. Turbidity at SKAGIT3, SKAGIT4, and SKAGIT7, flows at Newhalem and Marblemount, and spill at Gorge Dam during short-term continuous monitoring in June (top), July-August (middle), and August-September (bottom) (2022).**

Turbidity in grab samples collected monthly for laboratory analysis at mainstem Skagit River sites SKAGIT3, 4, and 5 was overall low (Table 5.3-8). Turbidity was less than 5 NTUs in all months, while turbidity at the farthest downstream site, SKAGIT7, was 5 NTUs and 7.2 NTUs in May and June, respectively. Turbidity values in Skagit River tributaries downstream of the Project, i.e., Newhalem Creek, and the Sauk and Baker rivers were typically less than 2 NTUs, with the highest turbidity levels observed during the May and June 2022 grab sampling events in the Baker River (BAKER1) in May (9.1 NTUs) and the Sauk River (SAUK1) in June (9 NTUs).

**Table 5.3-8. Turbidity measured by laboratory analysis from grab samples at Skagit River and tributary sites (May-September 2022).**

| Date | Turbidity (NTU) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | NEWCK | SKAGIT3 | MARB1 | CASC1 | SKAGIT4 | SKAGIT5 | SAUK1 | BAKER1 | SKAGIT7 |
| May 17, 2022 | 0.49 | .91H1 | NM | 1.3 | 1.2 | 1.2 | 2.4 | 9.1 | 5 |
| Jun 8, 2022 | 0.91 | 1.5 | NM | 4.5 | 2.2 | 2.5 | 9 | 3.9 | 7.2 |
| Jul 6, 2022 | 0.3 | 2.4 | NM | 1.4 | 2.2 | 3.5 | 4.1 | 1.7 | 4 |
| Aug 3, 2022 | ND | 1.1 | | 0.89 | 1 | 0.86 | 3.8 | 1.4 | 1.9 |
| Sep 22, 2022 | 0.35 | 0.5 | | 0.3 | 0.64 | 0.56 | 5.9 | 1.2 | 1.6 |

J qualifier assigned by Edge Lab indicates <PQL; NM = not measured.

NEWCK = Newhalem Creek below bridge near Rock Shelter Trail; SKAGIT3 = road mile 113; MARB1 = USGS Marblemount gage; CASC1 = Cascade River at Wagon Wheel Campground; SKAGIT4 = Glacier Peak; SKAGIT5 = Howard Miller Steelhead Park; SAUK1 = USGS Sauk River gage; BAKER1 = Baker River at WDFW access site; SKAGIT7 = Concrete.

### 5.3.6 Nutrients and Productivity

Overall, water chemistry data reported to date indicate low productivity within the system. Results of nutrients, chlorophyll *a*, carbon, and alkalinity (ALK) grab samples are shown below for samples collected from May through September 2022 (Table 5.3-9). Total Kjeldahl nitrogen (TKN), orthophosphate ($PO_4^{-3}$) and total phosphorus (TP) in the Skagit River and its tributaries were mostly below the PQL, shown as J qualified in the table below. While TKN and ammonia were low (less than the PQL of 0.2 mg/L and 0.01 mg/L, respectively), $NO_2$+$NO_3$ (Nox in Table 5.3-9) nitrogen concentrations were typically detectable, in contrast to TP, suggesting phosphorus limitation. The maximum $NO_x$ concentration was 0.09 mg/L in Newhalem Creek (NEWCK) in May 2022. Low nutrient levels in the Skagit River and its tributaries are consistent with results for the Project reservoirs, reflecting oligotrophic conditions (see Ross Lake section for an explanation of how conclusions were made regarding trophic status).

Chlorophyll *a* and pheophytin *a* were at or less than 1 µg/L at all sites, with the exception of chlorophyll *a* at SAUK1 in May (1.79 µg/L) and pheophytin at 2.6 µg/L at BAKER1 in May and 3.034 µg/L at SKAGIT3 in August. Levels of carbon (total and dissolved) in the Skagit River and tributaries downstream of the Project were typically less than 1 mg/L. Alkalinity was generally under 20 mg $CaCO_3$/L at all sites (maximum of 27.6 mg $CaCO_3$/L at SAUK1 in September), reflecting low ionic strength in the Skagit River and tributaries. Phytoplankton data will be analyzed when the complete set of phytoplankton taxonomic data is available.

**Table 5.3-9. Nutrients, chlorophyll a, carbon, and alkalinity in grab samples at Skagit River and tributary sites (May-September 2022).**

| Date | Site ID | $NH_3$-N (mg/L) | $NO_x$ (mg/L) | TKN (mg/L) | $PO_4^{-3}$ (mg/L) | TP (mg/L) | Chl *a* (µg/L) | Pheo *a* (µg/L) | CBOD (mg/L) | DOC (mg/L) | TOC (mg/L) | TIC (mg/L) | ALK (mg $CaCO_3$/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **May 17, 2022** | NEWCK | ND | 0.09 | 0.13J | ND | .0022J | ND | ND | 1 | 1.09 | 1.06 | 1.69 | 6.9 |
| | SKAGIT3 | ND | 0.06 | ND | .0094J | .0022J | .62J | ND | 1 | 0.84 | 0.86 | 5.1 | 20.7 |
| | MARB1 | NM | NM | NM | NM | NM | .75J | ND | NM | NM | NM | NM | 18.6 |
| | CASC1 | ND | 0.08 | .18J | .0034 J | .0058 J | ND | ND | 1 | 0.83 | 0.86 | 3.51 | 15.4 |
| | SKAGIT4 | ND | 0.06 | ND | .0037 J | .0035 J | .62J | ND | 1 | 0.82 | 0.87 | 4.53 | 19 |
| | SKAGIT5 | ND | 0.06 | ND | .0034 J | .0037 J | ND | ND | 1 | 0.8 | 0.84 | 4.64 | 19.4 |
| | SAUK1 | ND | 0.03 | ND | .0063 J | .0086 J | 1.79 | ND | 4 | 0.79 | 0.86 | 3.95 | 16.7 |
| | BAKER1 | ND | 0.06 | ND | 0.01 | 0.018 | .96J | 2.6 | 1 | 0.82 | 1.17 | 5.08 | 20.7 |
| | SKAGIT7 | ND | 0.05 | ND | .0066 J | .0090 J | 0.93J | ND | 1 | 0.92 | 0.88 | 4.44 | 18.1 |
| **Jun 8, 2022** | NEWCK | ND | 0.04 | ND | ND | .0051 J | 0.278 | 0.312 | 2 | 1.02 | 1 | NM | 4.8 |
| | SKAGIT3 | ND | 0.06 | 0.21 | .004 J | 0.011 | 0.418 | 0.306 | 1 | 0.88 | 0.86 | NM | 14.2 |
| | MARB1 | NM | NM | NM | NM | NM | 0.389 | 0.312 | NM | NM | NM | NM | 12.9 |
| | CASC1 | ND | 0.05 | ND | .005 J | 0.016 | 0.245 | 0.232 | 1 | 0.78 | 0.81 | NM | 10.4 |
| | SKAGIT4 | ND | 0.05 | ND | .004 J | .0075 J | 0.479 | 0.398 | 1 | 0.84 | 0.9 | NM | 12.3 |
| | SKAGIT5 | ND | 0.05 | ND | .0048 J | .0087 J | 0.463 | 0.369 | 1 | 0.79 | 0.86 | NM | 13.6 |
| | SAUK1 | ND | 0.02 | .06 J | .008 J | 0.019 | 0.602 | 0.516 | 1 | 0.81 | 0.88 | NM | 12 |
| | BAKER1 | ND | 0.04 | .07 J | .007J | .0092 J | 0.719 | 0.589 | 1 | 0.75 | 0.83 | NM | 15.9 |
| | SKAGIT7 | ND | 0.04 | .09 J | 0.006 J | 0.019 | 0.369 | 0.34 | 2 | 0.8 | 0.85 | NM | 13.5 |
| **Jul 6, 2022** | NEWCK | ND | 0.01 | ND | 0.0047 J | 0.0036 J | 0.371 | 0.378 | ND | 0.76 | 0.74 | NM | 4.9 |
| | SKAGIT3 | ND | 0.04 | ND | 0.0078 J | 0.014 | 0.299 | 0.23 | ND | 0.83 | 0.84 | NM | 20.6 |
| | MARB1 | NM | NM | NM | NM | NM | 0.296 | 0.229 | NM | NM | NM | NM | 20 |
| | CASC1 | ND | 0.02 | ND | 0.0057 J | 0.01 | 0.236 | 0.286 | ND | 0.62 | 0.57 | NM | 10.8 |
| | SKAGIT4 | ND | 0.03 | ND | 0.0077 J | 0.0062 J | 0.284 | 0.275 | ND | 0.8 | 0.87 | NM | 16.7 |
| | SKAGIT5 | ND | 0.03 | ND | 0.0079 J | 0.0091 J | 0.285 | 0.281 | ND | 0.79 | 0.78 | NM | 17 |
| | SAUK1 | ND | ND | 0.0083 J | 0.01 | 0.01 | 0.367 | 0.363 | ND | 0.63 | 0.6 | NM | 11.4 |
| | BAKER1 | ND | 0.03 | ND | 0.0084 J | 0.0043 J | 0.539 | 0.426 | ND | 0.8 | 0.8 | NM | 11.5 |
| | SKAGIT7 | ND | 0.02 | ND | 0.0090 J | 0.014 | 0.405 | 0.355 | ND | 0.76 | 0.74 | NM | 14.9 |

| Date | Site ID | $NH_3$-N (mg/L) | $NO_x$ (mg/L) | TKN (mg/L) | $PO_4^{-3}$ (mg/L) | TP (mg/L) | Chl *a* (µg/L) | Pheo *a* (µg/L) | CBOD (mg/L) | DOC (mg/L) | TOC (mg/L) | TIC (mg/L) | ALK (mg $CaCO_3$/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Aug 3, 2022** | NEWCK | ND | 0.03 | 0.096 J | 0.0075 J | 0.0032 J | 0.389 | 0.606 | ND | 0.47 J | 0.45 | NM | 6.4 |
| | SKAGIT3 | 0.012 | 0.04 | 0.12 J | 0.01 | 0.0047 J | 1.038 | 3.034 | ND | 0.7 | 0.72 | NM | 18.7 |
| | MARB1 | | | | | | | | | | | | 17.6 |
| | CASC1 | 0.01 | 0.02 | 0.11 J | 0.0069 J | 0.0059 J | 0.304 | 0.474 | ND | 0.35 J | 0.32 | NM | 12.2 |
| | SKAGIT4 | ND | 0.03 | ND | 0.0085 J | 0.0067 J | NR | NR | ND | 0.6 | 0.66 | NM | 16.6 |
| | SKAGIT5 | ND | 0.03 | ND | 0.0090 J | 0.0051 J | NR | NR | ND | 0.59 | 0.63 | NM | 17.7 |
| | SAUK1 | 0.012 | 0.0053 J | ND | 0.02 | 0.015 | 0.241 | 0.419 | ND | 0.40 J | 0.43 | NM | 13.8 |
| | BAKER1 | ND | 0.0091 J | ND | 0.01 | 0.0053 J | 0.729 | 0.57 | ND | 0.58 | 0.63 | NM | 10.2 |
| | SKAGIT7 | ND | 0.02 | 0.083 J | 0.01 | 0.0064 J | 0.402 | 0.48 | ND | 0.54 | 0.72 | NM | 15.7 |
| **Sep 22, 2022** | NEWCK | ND | 0.08 | ND | 0.0071 J | 0.0033 J | NR | NR | ND | 0.69 | 0.5 | NM | 9 |
| | SKAGIT3 | ND | 0.04 | ND | 0.0070 J | 0.0031 | NR | NR | ND | 0.94 | 0.84 | NM | 24 |
| | MARB1 | | | | | | NR | NR | | | | | 26.2 |
| | CASC1 | 0.0091 J | 0.05 | ND | 0.0066 J | 0.0033 J | NR | NR | ND | 0.5 | 0.44 | NM | 20 |
| | SKAGIT4 | ND | 0.04 | ND | 0.0065 J | 0.0071 J | NR | NR | ND | 0.84 | 0.89 | NM | 25.8 |
| | SKAGIT5 | 0.015 | 0.04 | ND | 0.0066 J | 0.0037 J | NR | NR | ND | 0.55 | 0.82 | NM | 25.9 |
| | SAUK1 | ND | ND | ND | 0.02 | 0.021 | NR | NR | ND | 0.54 | 0.53 | NM | 27.6 |
| | BAKER1 | ND | ND | ND | 0.0080 J | 0.0034 J | NR | NR | ND | 0.67 | 0.58 | NM | 12 |
| | SKAGIT7 | ND | 0.03 | ND | 0.0087 J | 0.0062 J | NR | NR | ND | 0.76 | 0.74 | NM | 24.4 |

Notes: $NH_3$-N = ammonia, $NO_x$= Nitrate+nitrite N, TKN=Total Kjeldahl N, $PO_4^{-3}$ = orthophosphate, TP = total phosphorus, Chl *a* = chlorophyll *a,* Phe *a* = Pheophytin *a*, CBOD = carbonaceous biochemical oxygen demand, DOC = dissolved organic carbon, TOC = total organic carbon, TIC = total inorganic carbon, ALK = alkalinity.

J qualifier assigned by Edge Lab indicates <PQL; ND=less than method detection, NM = not measured; NR = not yet reported by the laboratory.

SKAGIT3 = road mile 113; SKAGIT4 = Glacier Peak; SKAGIT5 = Howard Miller Steelhead Park; SKAGIT7 = Concrete. NEWCG = Newhalem Creek below bridge near Rock Shelter Trail; CASC1 = Cascade River at Wagon Wheel Campground; SAUK1 = USGS Sauk River gage; BAKER1 = Baker River at WDFW access site.

### 5.3.7 Periphyton

Preliminary results of chlorophyll *a* and pheophytin *a* measurements in periphyton are shown in Figure 5.3-27 for samples collected in May, June, and August, 2022 at PHOUSE1, SKAGIT3, SKAGIT4, and SKAGIT7. Concentrations in May were less than the laboratory's MDL at SKAGIT3. All other chlorophyll *a* values were less than 37 mg/m$^2$, well below 100 mg/m$^2$ threshold indicative of nuisance algal conditions (Krempa 2021).

Low pheophytin *a* values are an indication of minimal degradation of the chlorophyll *a* sample prior to analysis. Pheophytin *a* concentrations were less than 15 mg/m$^2$; indicating sample preservation was successful. Ash free dry weight results for periphyton samples have not yet been reported by the laboratory.

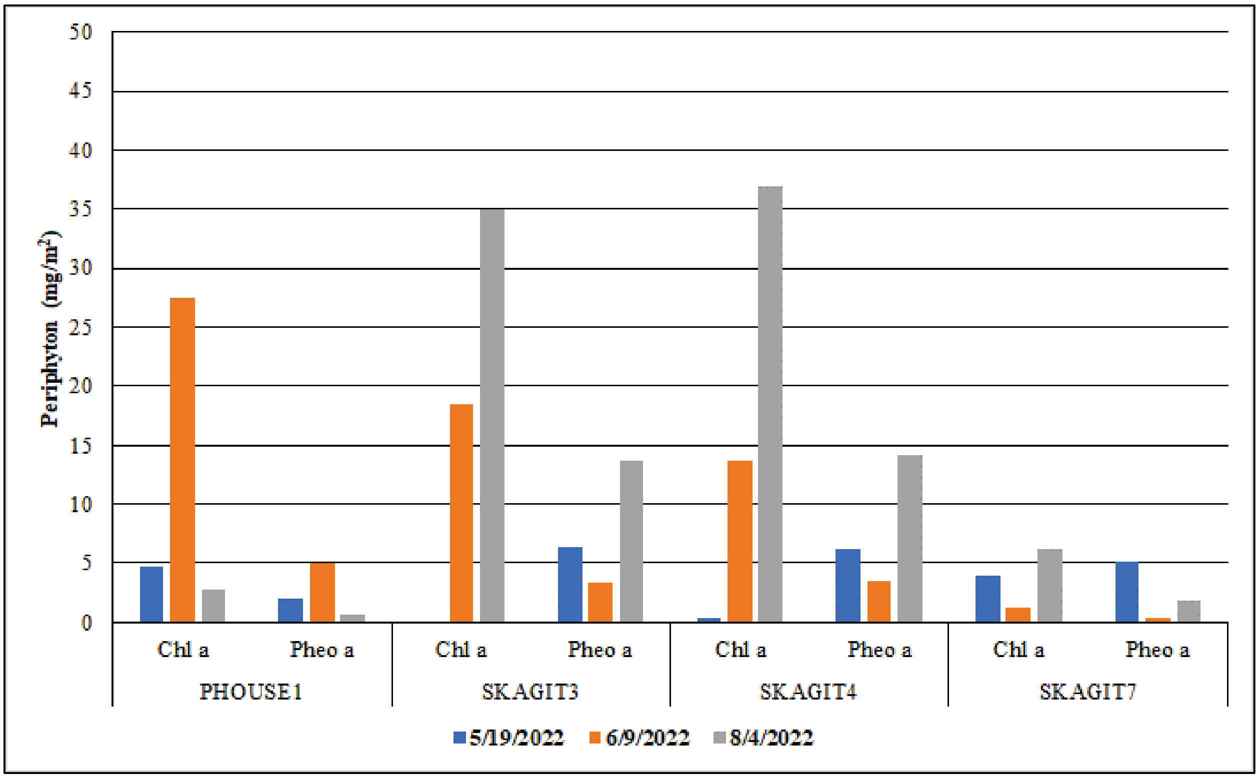



**Figure 5.3-27. Chlorophyll *a* and pheophytin *a* at PHOUSE1, SKAGIT3, SKAGIT4, and SKAGIT7 (May, June and August 2022).**

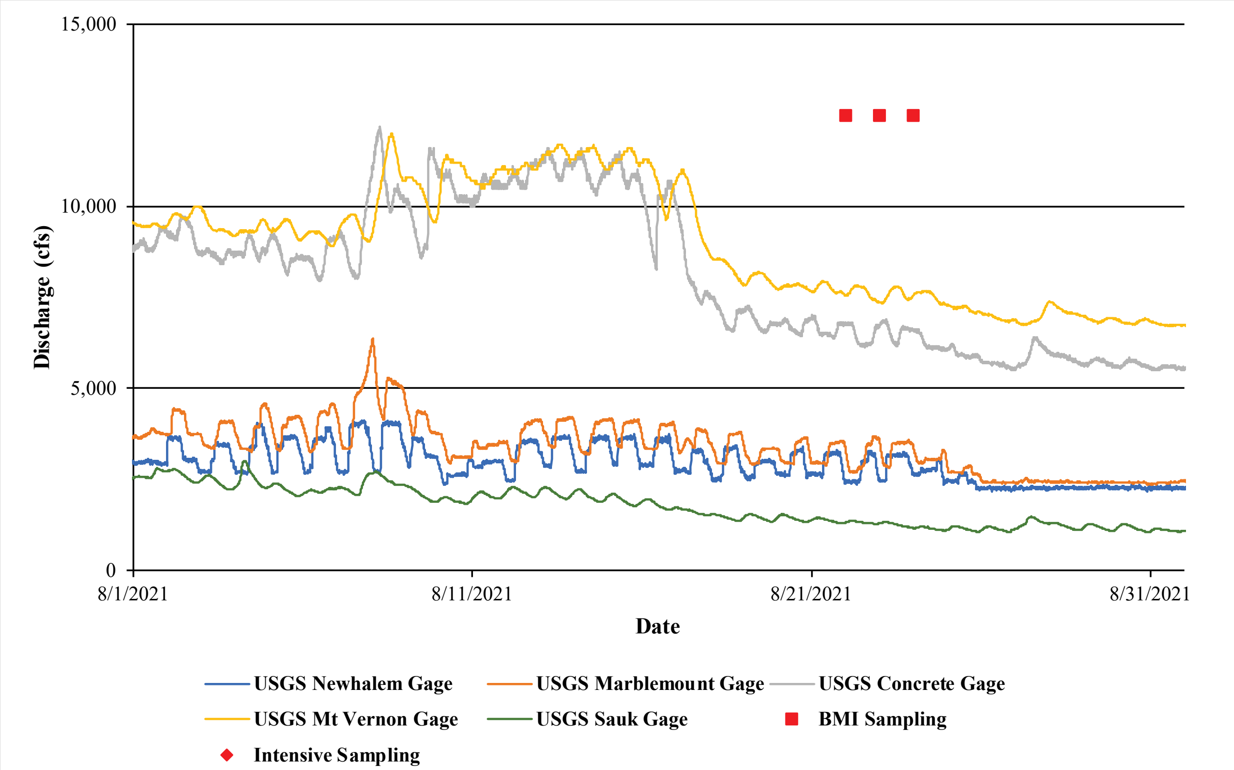
### 5.3.8 Benthic and Drifting Macroinvertebrates

#### 5.3.8.1 Longitudinal Kicknet Sampling

Sampling locations, methods, and frequencies for the macroinvertebrate data collection program are shown in Table 4.1-2. As described in Section 4, kicknet sampling for BMI and drift net sampling were conducted at lower river sites within wadable riffle habitat as close as possible to the thermograph locations listed in Table 4.1-1. In 2021, BMI sampling in July was not possible both due to unsafe conditions on the shoreline and high flows inundating sampling habitat that would not have been occupied by BMI at lower, more stable lows. Suitable conditions were not present until late August 2021. Similarly, the September 2021 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).

In 2022, BMI kicknet and drift sampling for sites within the Ross Lake National Recreation Area (SKAGIT2X and 3X) began in June, following permit issuance by NPS. Sampling at all other sites began in May. Macroinvertebrate samples were collected at roughly six-week intervals through October, with a final winter sampling event that occurred in February 2023 (and will be reported on in the addendum).

In general, Skagit River conditions at Concrete, Marblemount, and Newhalem during macroinvertebrate sampling were stable over the course of each of the five sampling events: August 2021 and May through August of 2022, allowing for kicknet sampling to occur at areas that had been occupied by BMI well before sampling. Skagit and Sauk River flows in August 2021 and from May through August 2022 are shown below (Figure 5.3-28).



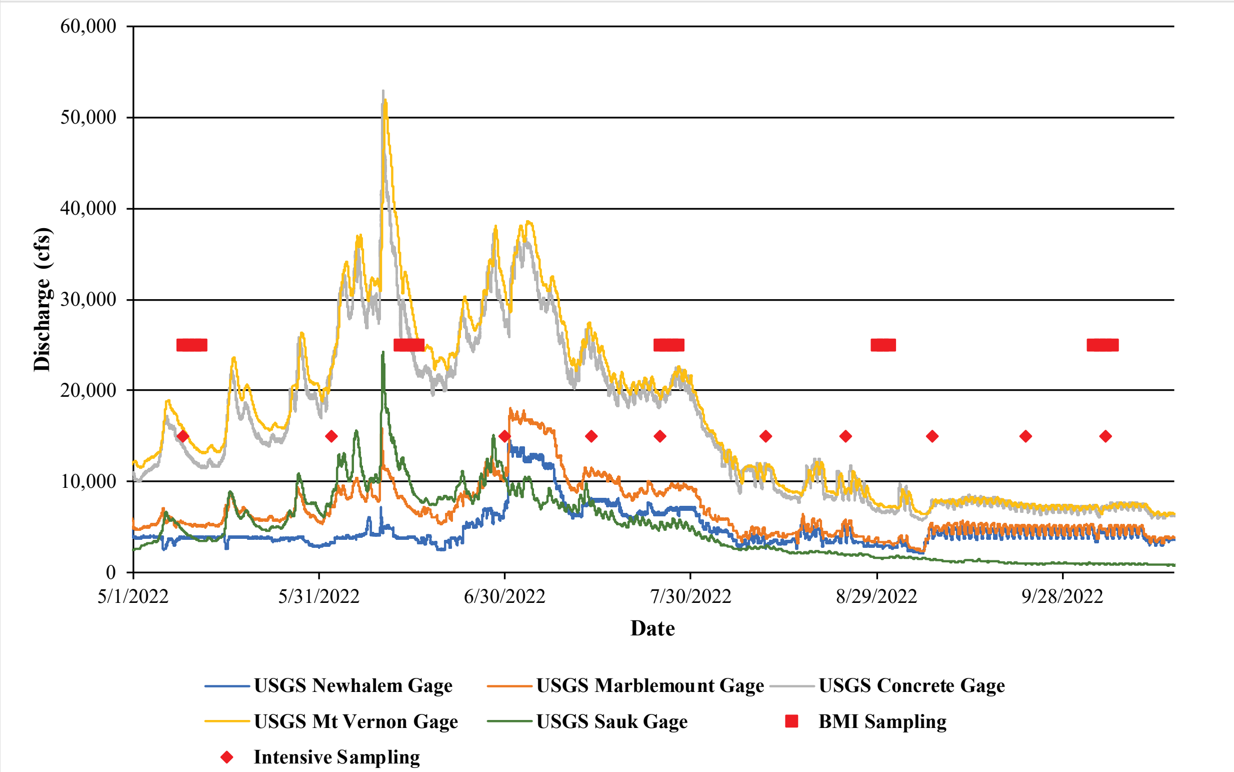




**Figure 5.3-28. Timing of macroinvertebrate sampling events and flows at USGS gages on the Skagit River at Newhalem (12178000), Marblemount (12181000), Concrete (12194000), and Mt. Vernon (12200500), and Sauk River (12189500) (August 2021, top) and (May-September 2022, bottom).**

Results for kicknet samples collected in the Sauk and Skagit River sites downstream of Gorge Powerhouse are shown below for abundance, taxa richness and percent EPT composition. Values reported for each of these metrics during each sampling event are shown below for main channel sites (Figure 5.3-29) and for main channel and side channel pairs (Figure 5.3-30). Averages for all sampling events for main channel sites are shown in Figure 5.3-31, and main and side channel pairs are shown in Figure 5.3-32.

BMI abundance was less than 5,000 individuals for most sampling events. Greater abundance was observed in August 2022 at SKAGIT3X (PRM 85.6, 29,290 individuals), SKAGIT7X (PRM 54.5, 8,086 individuals), and SKAGIT8X (PRM 42.2, 9,146 individuals). Abundance was also comparatively high in August 2021 at the two upstream-most sites on the Skagit River; SKAGIT2X (PRM 90.0) and SKAGIT3X (PRM 85.6) (18,974 and 13,758 individuals, respectively). Overall average abundance across all sampling events was highest at SKAGIT3X, and lowest at SKAGIT6X and 9X (Figure 5.3-31).

Total abundance at main channel and side channel pairs varied throughout the season and by site (Figure 5.3-30). Abundance at SKAGIT2SC was over 8,700 in August 2022, while abundance at SKAGIT2X was only around 400 at the same time. Abundance at these same sites were relatively even during the June and July sampling events, and the opposite pattern was true at SKAGIT8 in July 2022, when the main channel (SKAGIT8X) had an abundance of 1,210, and the side channel (SKAGIT8SC) had an abundance of around 500.

With few exceptions, taxa richness was above 30 taxa for each sampling event and over 60 in July 2022 at SKAGIT3X, within the Ross Lake National Recreation Area, and SKAGIT6X near Van Horn (PRM 59.7). Taxa richness was typically higher in July throughout the Skagit River.

A longitudinal trend in taxa richness was evident in kicknet samples collected in July 2022, with 63 taxa at SKAGIT3X near Marblemount, decreasing to 52 taxa at SKAGIT5X at Rockport (PRM 69.3), and to 24 taxa at SKAGIT6X at Van Horn, the lowest value reported during July and among all sampling events. Taxa richness increased markedly at the next downstream location (53 taxa at SKAGIT7X at Concrete), and values declined from there to SKAGIT8X and SKAGIT9X (PRM 23.1), 40 and 36 taxa, respectively. However, the second highest taxa richness was observed at SKAGIT6X in August (61 taxa). These within site differences likely reflect varying microhabitat within the available sample area, e.g., substrate size and quality.

Taxa richness observed at the Sauk River site (SAUK1, RM 5.4) in August 2021 were similar to May-August of 2022 (Figure 5.3-29). Taxa richness at the Sauk River site was similar to Skagit River sites, ranging from 37 taxa in June 2022 to 54 taxa in July 2022. Average taxa richness was relatively similar for all sites, ranging from 35 taxa at SKAGIT9X to 46 taxa at SKAGIT3X, SKAGIT7X, and SAUK1X (Figure 5.3-31).

Main channel/side channel pairs had similar taxa richness for all sampling events with the exception of SKAGIT6X/SC in July 2022, when the side channel had more than double the number of taxa (Figure 5.3-30). Average taxa richness was higher at each of the three side channels than the corresponding main channel site (Figure 5.3-32).

Percent EPT composition was consistently high for all sampling events at SKAGIT5X, and varied throughout the season at all other sites. Average percent EPT composition for main channel sites during all visits was 35 percent, with a high of 64 percent for SKAGIT5X (at Rockport). Percent EPT composition was 52 percent at SKAGIT2X in the Ross Lake National Recreation Area in samples collected in 2022 compared to 22 percent in August 2021 (based on a single visit). Notably, while taxa richness was relatively similar among main channel sites, percent EPT composition was more variable and tended to decrease with distance downstream. Average percent EPT composition was higher at the side channel than the corresponding main channel site for the furthest downstream site near Sedro-Woolley (SKAGIT8X), but higher at the main channel sites at SKAGIT6X and SKAGIT2X (Figure 5.3-32). Percent EPT composition was always higher in the main channel than the side channel at SKAGIT2X, the furthest upstream site closest to Newhalem.

Functional group composition is shown in Figure 5.3-33. BMI classified as gatherers were typically most abundant except for in May 2022 at SKAGIT9X when filters comprised almost the entire sample, and in June 2022 at SKAGIT5X when predators were slightly more numerous than gatherers. Piercer herbivores were consistently least abundant. While gatherers were typically the most well represented group among sites visited in 2022, the composition of other groups varied from May through August. Notably, shredders were absent or a minor component of the community at upstream sites in May and June, but were an important fraction in July and more so in August, likely a reflection of increasingly available allochthonous material as the growing season progresses. Shredders accounted for 20-40 percent of the samples from the sites downstream from the Sauk River (SKAGIT6X-SKAGIT9X) collected in August.

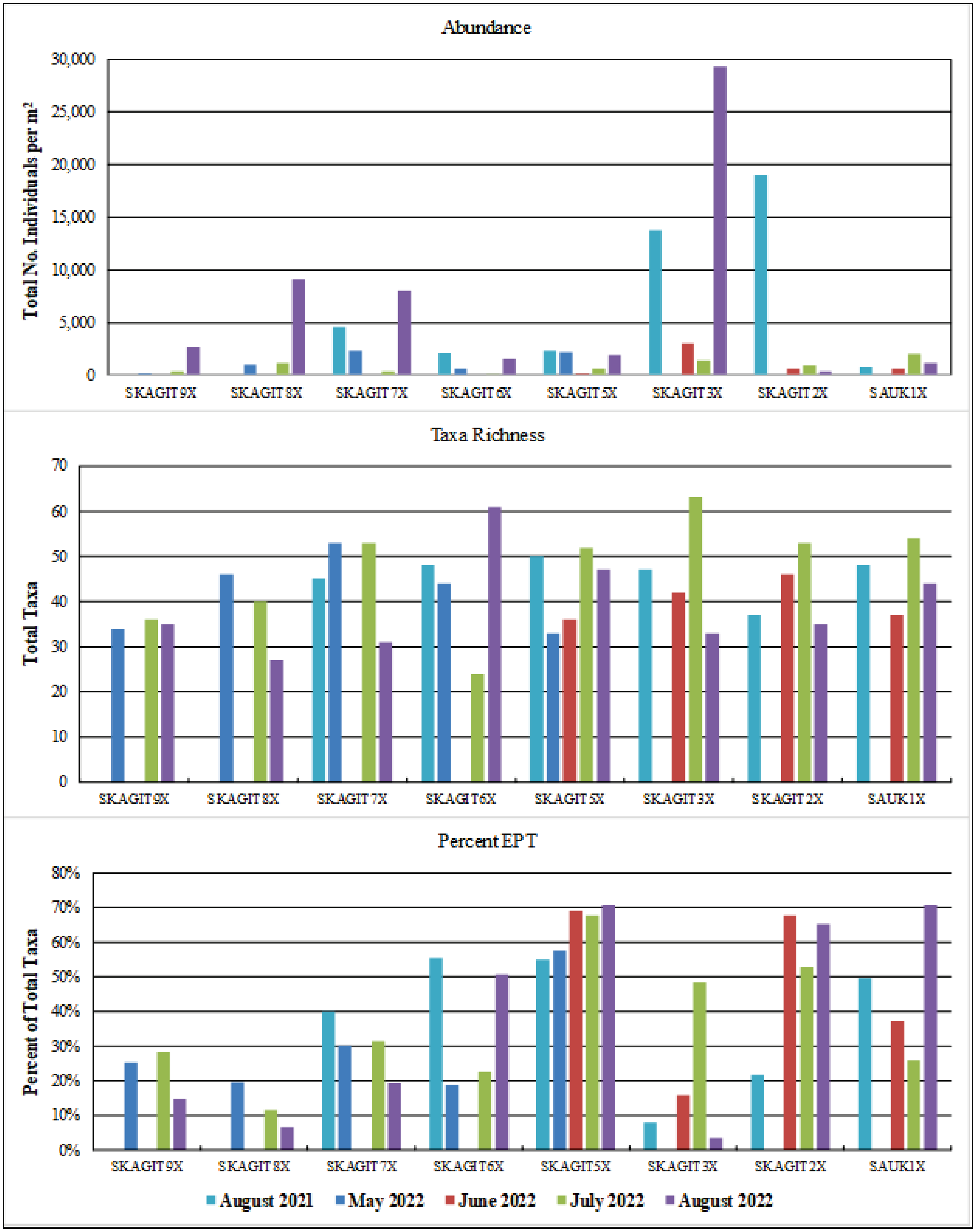



**Figure 5.3-29. Abundance (top), taxa richness (middle) and percent EPT composition (bottom) for kicknet samples at Skagit and Sauk River main channel sites (August 2021 and May-August 2022).**

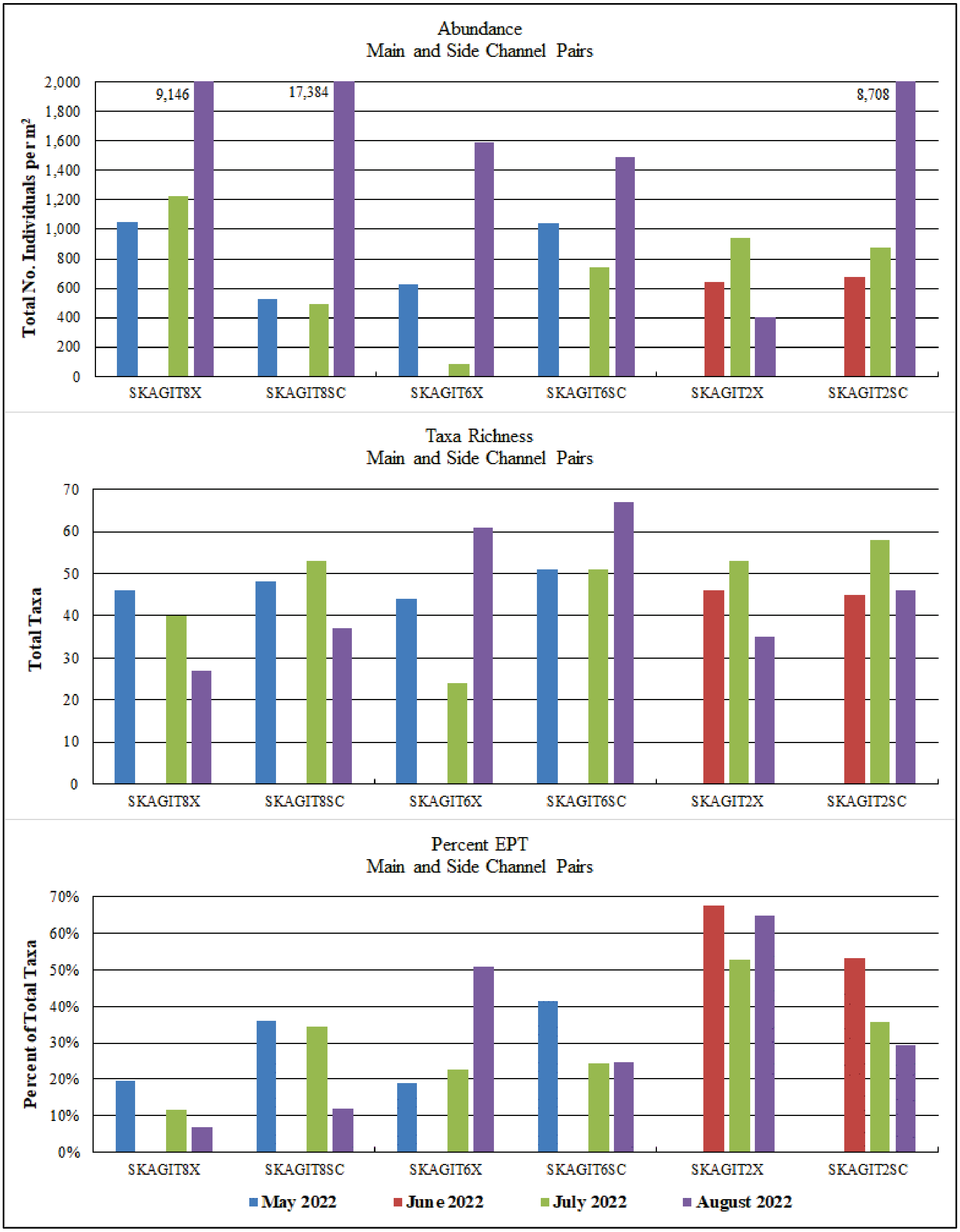



**Figure 5.3-30. Abundance (top), taxa richness (middle) and percent EPT composition (bottom) for kicknet samples at paired Skagit River main channel and side channel sites (May-August 2022).**

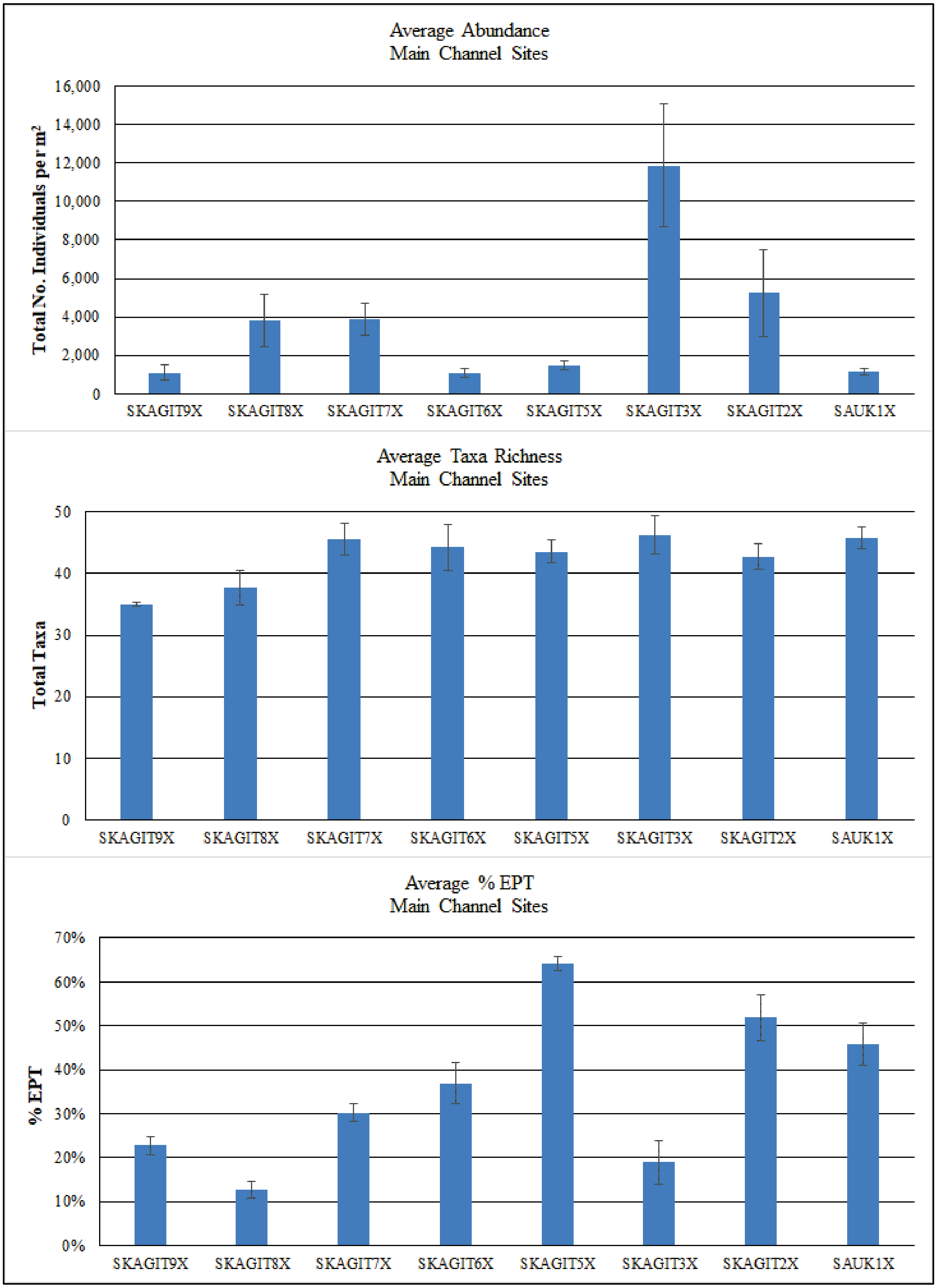



**Figure 5.3-31. Average abundance (top), taxa richness (middle) and percent EPT composition (bottom) at Skagit River and Sauk River main channel sites (2021-2022). Vertical bars show standard error.**

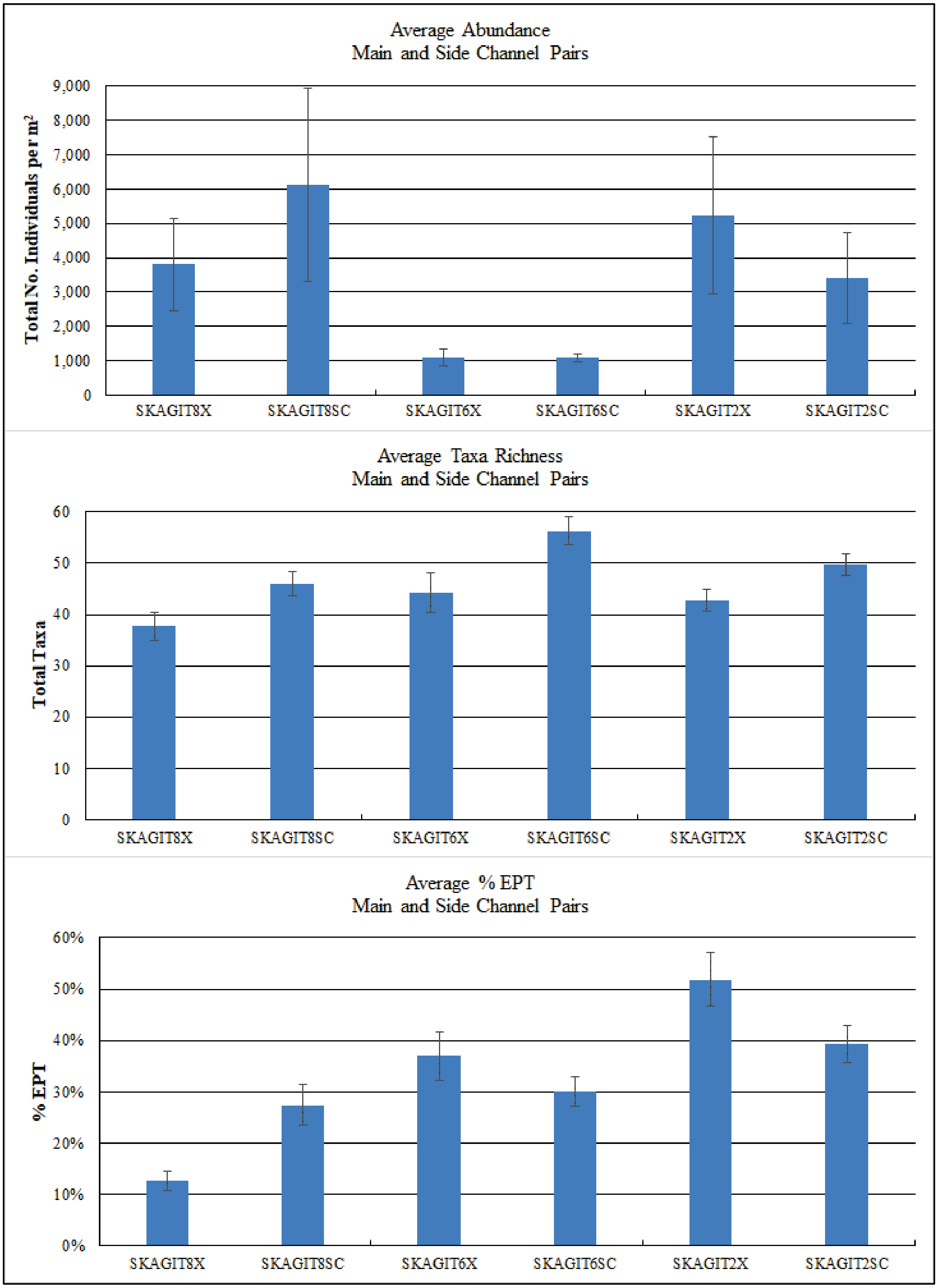



**Figure 5.3-32. Average abundance (top), taxa richness (middle) and percent EPT composition (bottom) at Skagit River and Sauk River main and side channel pairs (May-August 2022). Vertical bars show standard error.**

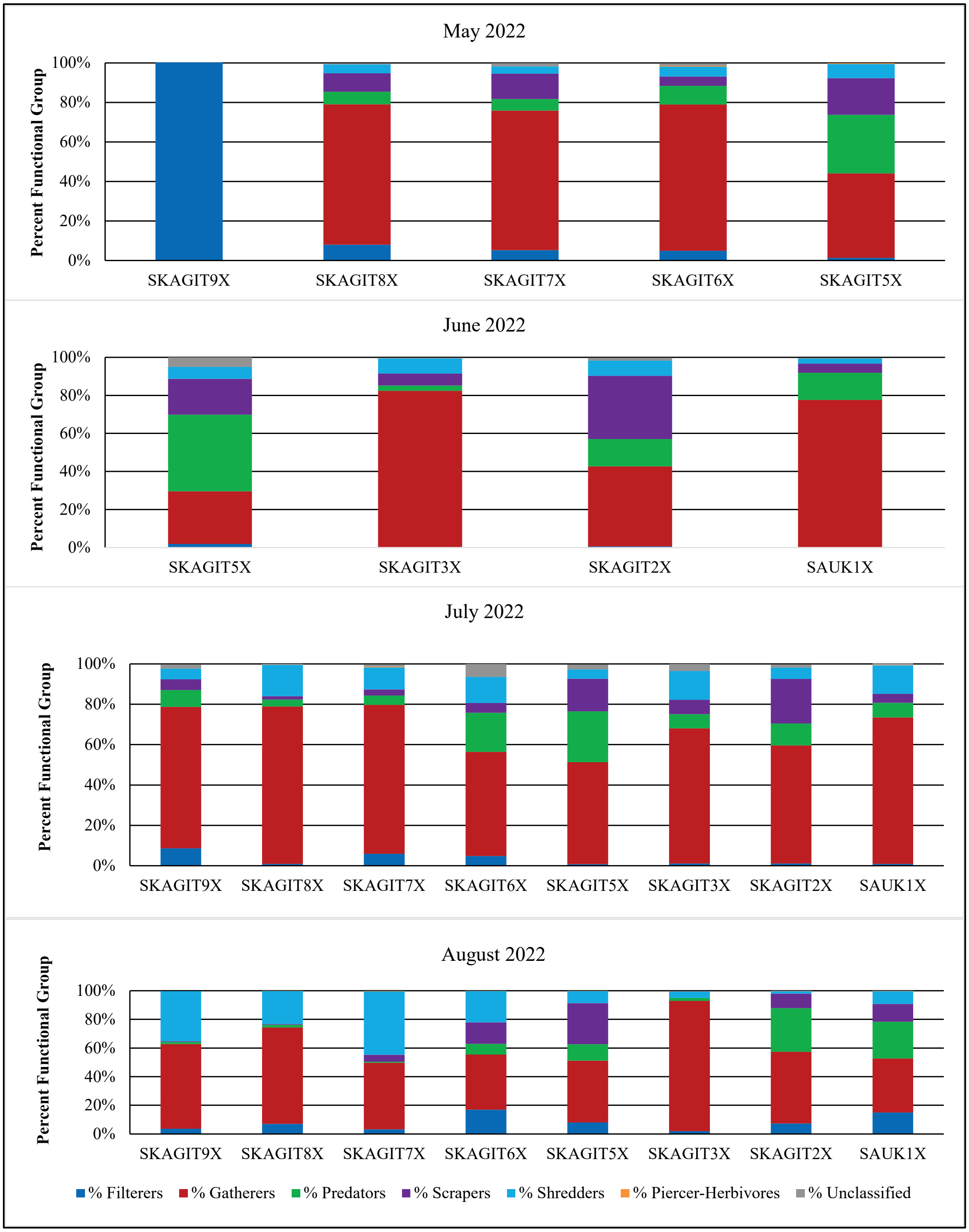



**Figure 5.3-33. Functional group composition at Skagit river and Sauk River sites (May-August 2022).**

Paired macroinvertebrate drift samples were collected at each of the kicknet sites on the mainstem Skagit River. Drift data were only available for May 2022 and are therefore not included in this study report. Kicknet data, including data for side channel sites, are reported through August 2022. Macroinvertebrate data will be analyzed further when the complete set of taxonomic data is available.

#### 5.3.8.2 Intensive Transect Sampling

As described in Section 4, intensive BMI sampling at sites in the Skagit River (SKAGIT4X, regulated) at PRM 72.0 and the Sauk River (SAUK2X, unregulated), just upstream of the confluence with the Suiattle River at RM 13.2, began in 2022. At each site, kicknet samples were collected at five locations along a transect in the main channel from the maximum wadable depth (MC1) to the shoreline (MC5), and another three samples along this transect within a side channel (SC1-SC3). Intensive sampling occurred in May and June and continued every two weeks from July-October, and every four weeks from November-December 2022. Sampling will continue at four-week intervals from March-June 2023, unless high flows prohibit site access.

For each of the two intensive sampling locations, samples were collected in the main and side channel sites on a single day for all sampling events (May 11, June 2, July 25, August 11, August 25) with the exception of June 2022. High flows prevented wading access to the Skagit River main channel until June 14, when the site was accessed via boat. Results from intensive BMI sampling sites are presented below as averages for the first five monitoring events at each site for abundance, taxa richness, and percent EPT composition.

Average abundance was higher at the Skagit River main channel transect (1,228-1,896 individuals) than along the Sauk River main channel transect (1,145-1,515 individuals) at four of the five locations. Abundance at the Skagit River side channel transect was substantially higher (2,147-2,621 individuals) than the Sauk River side channel transect (500-1,673 individuals) (Figure 5.3-34).

Average taxa richness was slightly higher at the Sauk River main channel transect (21-28 taxa) than the Skagit River main channel transect (20–26 taxa). However, taxa richness was consistently higher at the Skagit River side channel transect (27-29 taxa) than at the Sauk River side channel transect (13-22 taxa), likely due to more consistent depth and inundation of the Skagit River side channel (Figure 5.3-35).

Percent EPT composition was consistently higher along the Sauk River main channel transect (42-54 percent) than along the Skagit River main channel transect (33-41 percent). In contrast, percent EPT composition was consistently higher along the Skagit River side channel transect (37-47 percent) than along the Sauk River side channel transect (26-30 percent) (Figure 5.3-36).

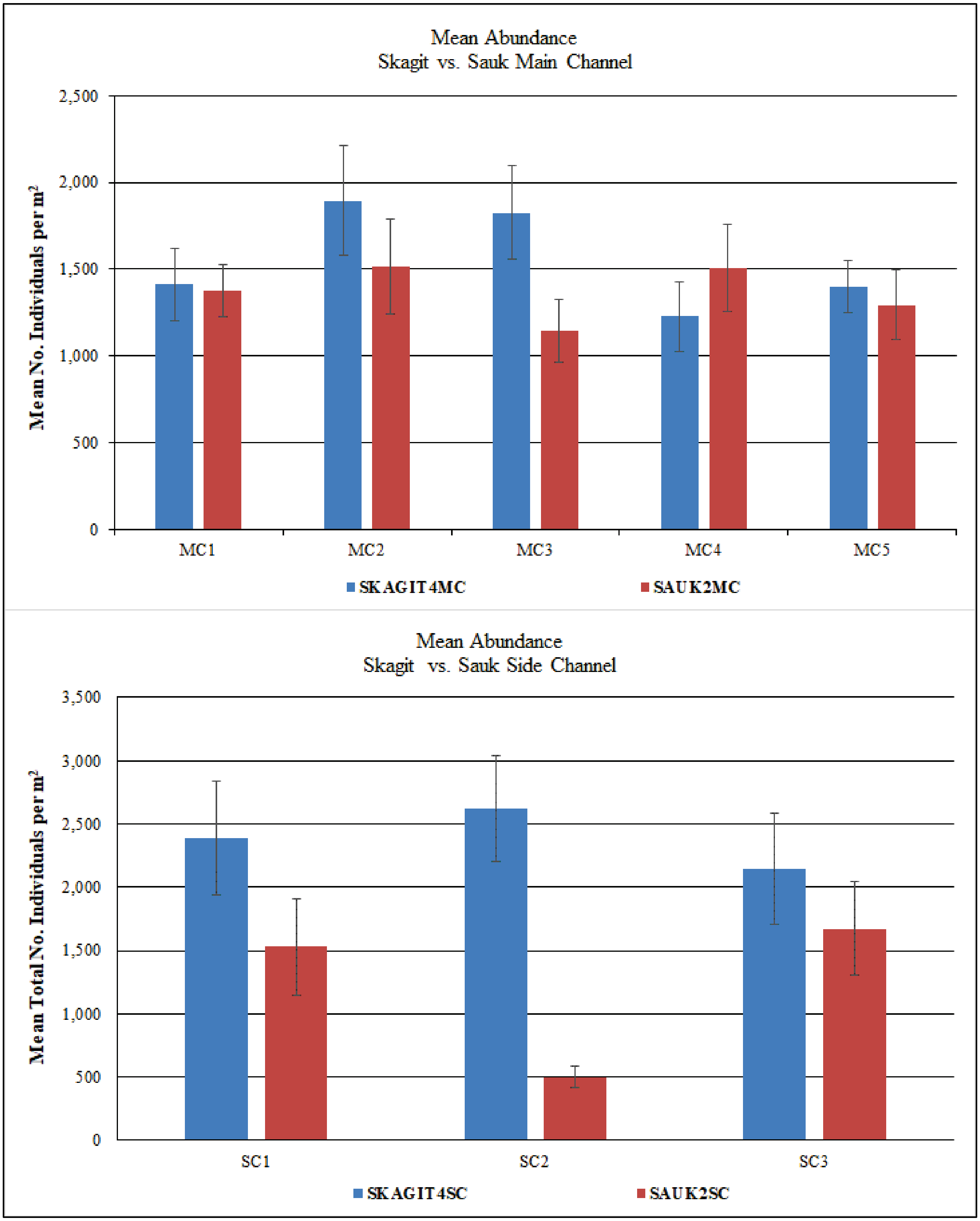



**Figure 5.3-34.** **Mean abundance at intensive BMI main channel sites (top) and side channel sites (bottom). Averages based on five visits to each site (May-August 2022). Vertical bars show standard error.**

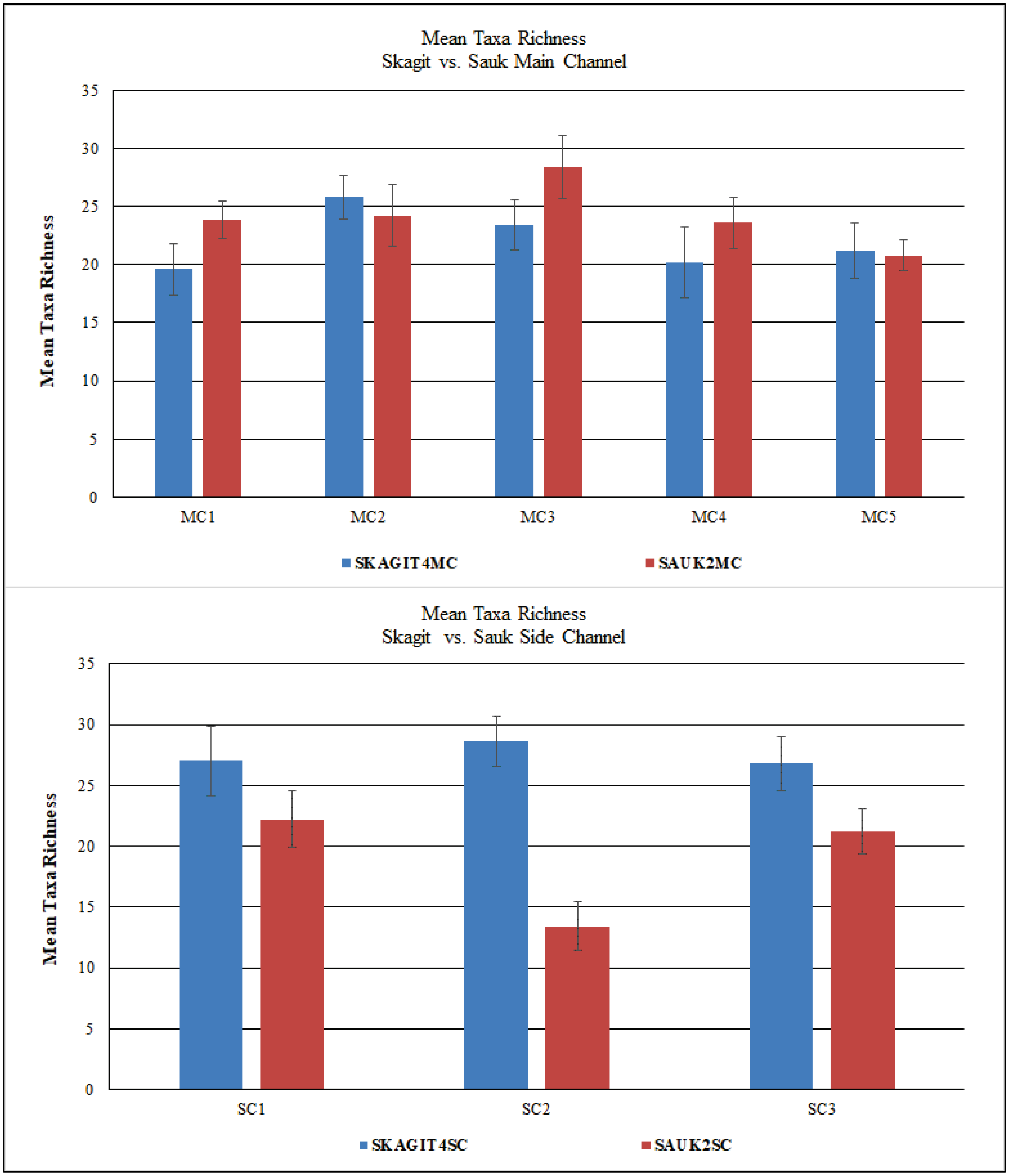



**Figure 5.3-35. Mean taxa richness at intensive BMI main channel sites (top) and side channel sites (bottom). Averages based on five visits to each site from (May-August 2022). Vertical bars show standard error.**

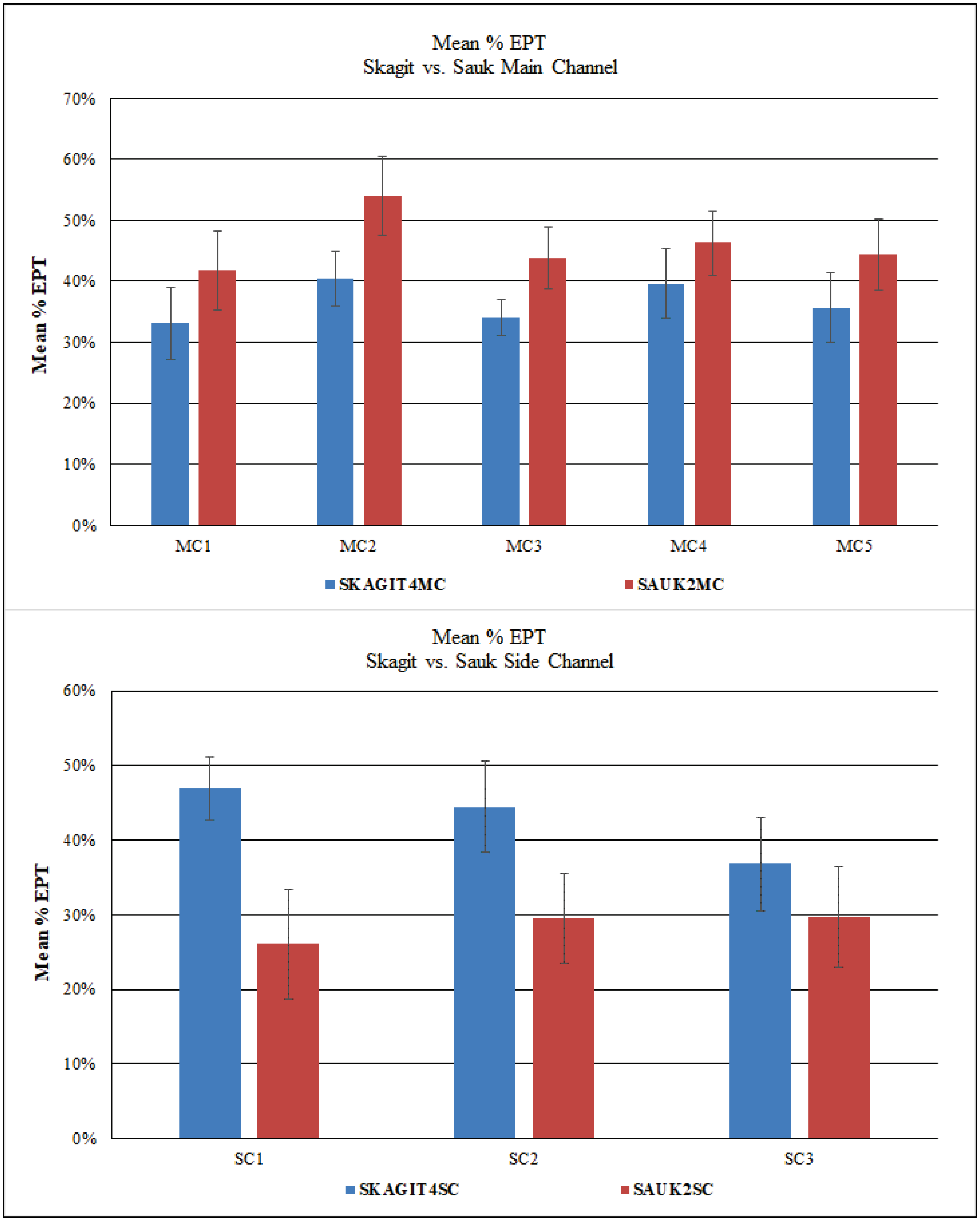



**Figure 5.3-36. Mean percent EPT composition at intensive BMI main channel sites (top) and side channel sites (bottom). Averages based on five visits to each site (May-August 2022). Vertical bars show standard error.**

Two thermographs were deployed at each of the two transect sites to continuously monitor temperature at each of the macroinvertebrate sampling sites (Table 5.3-10). Thermographs were installed in the Skagit River on July 27, 2022, and in the Sauk River on July 28, 2022. There was little difference in temperature between the two Skagit River sites from July through early October. Average temperatures at the Skagit River main and side channel sites were 12.2 and 12.4°C, respectively, while temperatures at the Sauk River main and side channel sites differed significantly, averaging 15.2 and 12.6°C, respectively (Table 5.3-6). Greater differences were measured at the two Sauk River sites during mid-August and mid-September (Figure 5.3-37). As noted earlier, the highest 7-DADMax water temperature in 2022 was recorded at SAUK2 (18.5°C).

**Table 5.3-10. Minimum, average, and maximum hourly temperatures at intensive monitoring sites (July 27-October 5, 2022).**

| Site ID | Min (°C) | Average (°C) | Max (°C) |
|---|---|---|---|
| SKAGIT4 | 9.7 | 12.2 | 15.3 |
| SKAGIT4SC | 10.3 | 12.4 | 15.6 |
| SAUK2 | 10.8 | 15.2 | 19.3 |
| SAUK2SC | 8.6 | 12.6 | 18.0 |

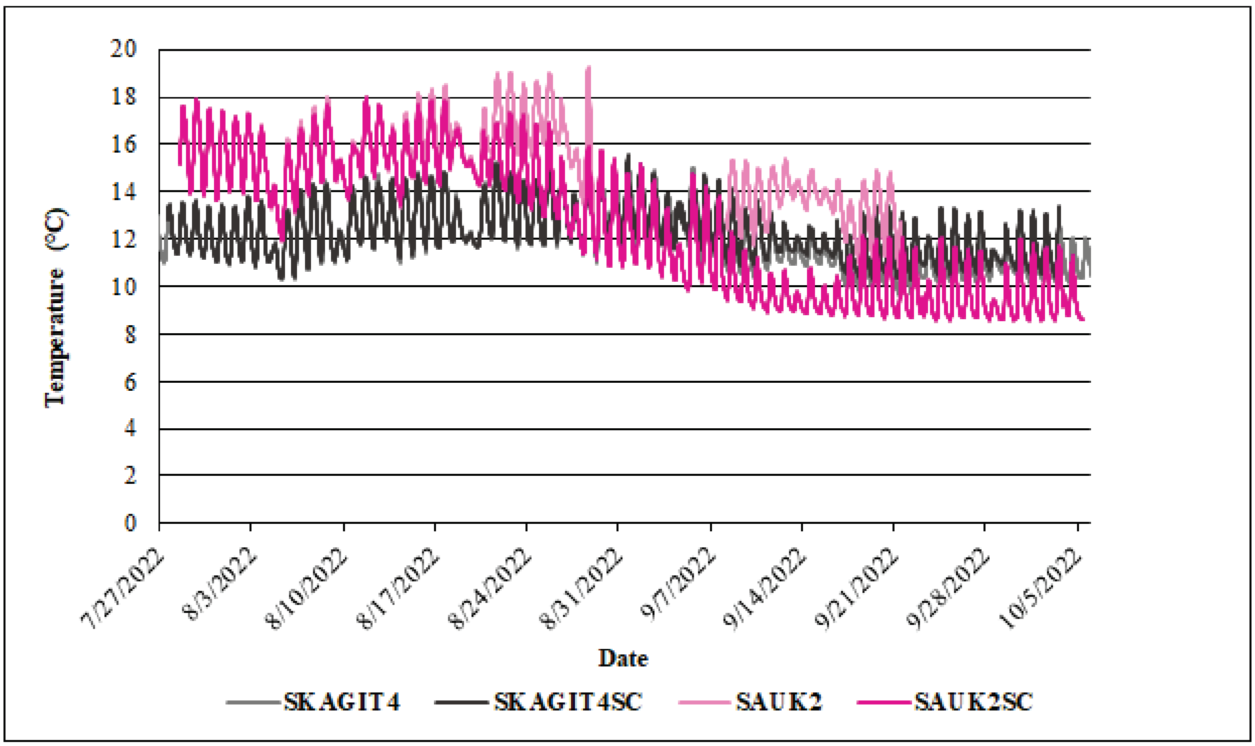



**Figure 5.3-37. 30-minute water temperatures at intensive BMI sampling sites (July 27-October 5, 2022).**

Nutrient samples are also being collected at the SAUK2 main channel on a quarterly basis to allow for a comparison of conditions before and after the influx of marine-derived nutrients (MDN) from spawned-out salmon and steelhead carcasses, and for comparison with SKAGIT4 nutrient levels already being collected in support of CEQUAL-W2 modelling. Nutrient samples collected on August 3, 2022 and October 27 and 28, 2022 (SKAGIT4 and SAUK2, respectively) reflect pre- and post-spawning activity in the Skagit River for Chinook Salmon. Chinook Salmon spawning occurs from late August through early October for summer Chinook Salmon, and Late September through October for Fall Chinook Salmon (City Light 2022b).

Nitrate ($NO_x$) increased 0.02 mg/L from August to October at SKAGIT4; an increase of over 60 percent (Table 5.3-11). A larger increase was seen at the SAUK2 site; nitrate increased from ND (less than the MDL of 0.006 mg/L) to 0.07 mg/L, a minimum of a 12-fold increase. Total phosphorus was less than the PQL at SKAGIT4 but above it at SAUK2, and unchanged from August to October. Phosphorus levels at SKAGIT4 were less than the PQL, and ammonia and TKN were also less than reporting limits at both sites. Results suggest an influx of nitrogen; whether derived from salmon carcasses, nitrogen-fixing alder, or other source is unknown.

**Table 5.3-11. Nutrient concentrations at intensive BMI sampling sites (August 3 and October 26, 2022).**

| Analyte (mg/L) | SKAGIT4 | | SAUK2 | |
|---|---|---|---|---|
| | August 3, 2022 | October 26, 2022 | August 3, 2022 | October 27, 2022 |
| $NH_3$-N | ND | ND | ND | ND |
| $NO_x$ | 0.03 | 0.05 | ND | 0.07 |
| TKN | ND | 0.079J | 0.13J | ND |
| $PO_4^{-3}$ | 0.0085J | 0.0071J | 0.02 | NM |
| TP | 0.0067J | 0.0031J | 0.011 | 0.012 |

Notes: J=less than practical quantitation limit (PQL), ND=less than MDL, NM=not measured.
$NH_3$-N = ammonia; $NO_x$= Nitrate+nitrite N; TKN=Total Kjeldahl N; $PO_4^{-3}$ = orthophosphate; TP = total phosphorus.

## 5.3.9 QA/QC

As described in Section 4.1, field duplicates were collected for water quality grab and benthic macroinvertebrate samples (all drift samples were collected in replicate). These samples, in addition to internal laboratory QA/QC measures, are used assess sample variability due to either field conditions or the sample collection process. Duplicate precision, or visit precision as discussed in the Project QAPP, is assessed using RSD, a ratio of the standard deviation to the mean of the duplicate pair. Percent RSD is discussed below for water quality grab samples and benthic macroinvertebrates at lower river sites.

### 5.3.9.1 Water Quality

Duplicate precision, shown as percent RSD for analytes measured in grab samples at lower river sites is shown in Table 5.3-12. Per the Project QAPP, the RSD for field duplicate pairs should be within 10 percent for laboratory analytes (5 percent for turbidity). However, as seen previously in this study report, RSDs can be high when the denominator ($x_{avg}$) is a small number, as is common for turbidity and most other analytes. In these cases, the RSD criteria can be exceeded because a small (likely acceptable) standard deviation is being compared with another small number (the average of the sample pair). RSD results should therefore be viewed with caution and are not necessarily indicative of unacceptable variability.

**Table 5.3-12. Percent RSD for turbidity, nutrients, and carbon measurements for field duplicates collected at lower Skagit River sites (May-September 2022).**

| Analyte | May 19, 2022 (SKAGIT5) | | | June 8, 2022 (BAKER1) | | | July 6, 2022 (CASC1) | | | August 3, 2022 (SKAGIT4) | | | September 9, 2022 (SAUK1) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | R | D | %RSD | R | D | %RSD | R | D | %RSD | R | D | %RSD | R | D | %RSD |
| Turbidity (NTU) | 1.20 | 1.10 | **6.1** | 3.90 | 3.50 | **7.6** | 1.80 | 1.40 | **17.7** | 1.00 | 1.20 | **12.9** | 5.90 | 6.40 | **5.7** |
| $NH_3$-N (mg/L) | ND | ND | | ND | ND | | ND | ND | | ND | ND | | ND | ND | |
| TKN (mg/L) | ND | ND | | 0.07 | ND | | ND | ND | | ND | ND | | ND | ND | |
| TSS (mg/L) | 2.00 | 2.00 | **0.0** | 4.00 | 3.00 | **20.2** | 5.50 | 5.50 | **0.0** | ND | 2.00 | | 2.00 | 9.00 | **90.0** |
| ALK (mg $CaCO_3$/L) | 19.40 | 19.40 | **0.0** | 15.90 | 15.70 | **0.9** | 10.50 | 10.80 | **2.0** | 16.60 | 16.70 | **0.4** | 27.60 | 27.50 | **0.3** |
| $NO_x$ (mg/L) | 0.06 | 0.06 | **0.0** | 0.04 | 0.04 | **0.0** | 0.02 | 0.02 | **0.0** | 0.03 | 0.03 | **0.0** | ND | ND | |
| $PO_4^{-3}$ (mg/L) | 0.0034 | 0.0033 | **2.1** | 0.0070 | 0.0070 | **0.0** | 0.0060 | 0.0057 | **3.6** | 0.0085 | 0.0100 | **11.5** | 0.0200 | 0.0200 | **0.0** |
| TP (mg/L) | 0.0037 | 0.0049 | **19.7** | 0.0092 | 0.0081 | **9.0** | 0.0100 | 0.0100 | **0.0** | 0.0067 | 0.0065 | **2.1** | 0.0210 | 0.0200 | **3.4** |
| CBOD (mg/L) | 1.00 | 1.00 | **0.0** | 1.00 | 1.00 | **0.0** | ND | ND | | ND | ND | | ND | ND | |
| TOC (mg/L) | 0.84 | 0.86 | **1.7** | 0.83 | 0.80 | **2.6** | 0.56 | 0.57 | **1.3** | 0.66 | 0.84 | **17.0** | 0.53 | 0.54 | **1.3** |
| DOC (mg/L) | 0.80 | 0.85 | **4.3** | 0.75 | 0.82 | **6.3** | 0.60 | 0.62 | **2.3** | 0.60 | 0.62 | **2.3** | 0.54 | 0.64 | **12.0** |
| Chl *a* (µg/L) | | | | 0.719 | 0.777 | **5.5** | | | | | | | | | |
| Pheo *a* (µg/L) | | | | 0.589 | 0.642 | **6.1** | | | | | | | | | |
| TIC (mg/L) | 4.64 | 4.62 | **0.3** | ND | ND | | ND | ND | **ND** | ND | ND | **ND** | ND | ND | **ND** |

Notes: ND=less than PQL, NM = not measured.

$NH_3$-N = ammonia; $NO_x$= Nitrate+nitrite N; TKN=Total Kjeldahl N; $PO_4^{-3}$ = orthophosphate; TP = total phosphorus; Chl *a* = chlorophyll *a;* Phe *a* = Pheophytin *a*; CBOD = carbonaceous biochemical oxygen demand; DOC = dissolved organic carbon; TOC = total organic carbon; TIC = total inorganic carbon; ALK = alkalinity.

SKAGIT5 = Howard Miller Steelhead Park; BAKER1 = Baker River at WDFW access site; CASC1 = Cascade River at Wagon Wheel Campground; SKAGIT4 = Glacier Peak; SAUK1 = USGS Sauk River gage.

RSDs for ammonia and TKN could not be calculated given reported values are less than PQL in one or both duplicate pairs. Nutrients, carbon (TOC and DOC), and alkalinity were well under 10 percent. RSD values for TSS were highest among all analytes; ranging from zero in the May duplicate to 90 percent in September. TSS is a gravimetric analysis and variability may be a result of the weighing process in the lab, settling in the sample bottle or natural variability in particulates captured in the samples. Turbidity also routinely exceeded the QAPP criteria of 5 percent. In this case, as noted above, relatively high RSDs (6-18 percent), can be attributed to the low values reported, which ranged from 1-6 NTUs.

All thermographs were checked before deployment by comparing the temperature to a Certified Reference Thermometer traceable to the National Institute of Standards and Technology following Ecology SOP EAP080 (Ecology 2018b). All thermographs passed field verification of measurements conducted with a Certified Reference Thermometer. All water temperature data was reviewed, and anomalous data, identified by comparing any questionable results to ambient monitoring temperature data, flow information, and field notes, was removed from analysis.

#### 5.3.9.2 Benthic and Drifting Macroinvertebrates

As discussed in the Project QAPP, duplicate (visit) precision is calculated using the RSD from two replicate composite samples and should be less than 20 percent in reference streams when using the taxa richness metric. Percent RSD of macroinvertebrate metrics discussed in this section (abundance, taxa richness, percent EPT composition) are shown below for four duplicate pairs collected during visits to Skagit River sites in May, June, July, and August 2022 (Figure 5.3-38).

Percent RSD values were less than the 20 percent RSD as specified in the QAPP for all macroinvertebrate metrics reported herein; variability was 11 percent for taxa richness and 19 percent for percent EPT composition.

Replicate macroinvertebrate drift samples were collected at each of the kicknet sites on the mainstem Skagit and Sauk rivers. Duplicate precision will be evaluated after sample results are received from the laboratory.

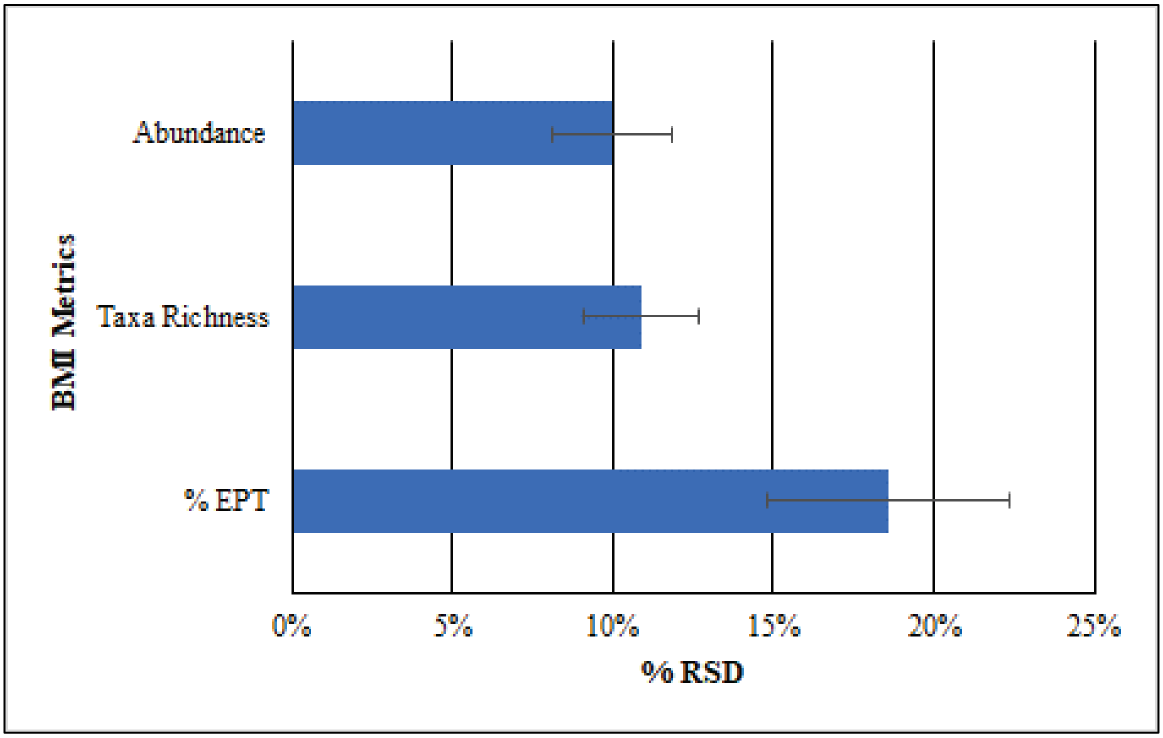



**Figure 5.3-38. Mean RSD for BMI metrics based on four sampling events at four Skagit River sites (May-August 2022). Error bars show standard error.**

# 6.0 DISCUSSION AND FINDINGS

The WQ Monitoring Study has met the goals and objectives stated in Section 2.0 of this study report, which is to monitor water quality parameters for which existing information is insufficient to characterize conditions within the study area.

Results of data collection described in this study report extend from early action beginning in September 2020 (thermograph sites SKAGIT2, SKAGIT3 and SKAGIT4) through early fall 2022. Based on the two-year schedule for fieldwork outlined in the FERC-approved study plan (June 2021 – May 2023), data reported in this study report represent 16 of the planned 24 months, or roughly 70 percent of the total monitoring period. Results of monitoring through May 2023 will be included in an addendum to this report.

This study report includes results of monitoring conducted over and above the activities directed by the FERC-approved study plan ("expanded program"). The expanded program was agreed to by City Light in the June 9, 2021 Notice to provide (1) water quality data needed for development and calibration of the CE-QUAL-W2 water quality model (FA-01b WQ Model Development Study, City Light 2023a), in large measure to enable the modeling of nutrients and productivity; and (2) a comprehensive BMI and invertebrate drift data collection program requested by LPs. Focused studies were undertaken to assess BMI colonization of the Ross Lake varial zone and assessment of potential differences in BMI communities between the Skagit River (regulated) and Sauk River (unregulated). These activities are ongoing, and additional results will be included in the subsequent addendum.

This report also includes select data collected by City Light and other entities outside the context of Project relicensing, i.e., information which was augmented by that gathered as part of relicensing. This includes temperature, water chemistry, and zooplankton information for the Project reservoirs, collected by City Light and NCCN, and summaries of water quality data collected by Ecology in the Skagit River and Ross Lake.

## 6.1 Project Reservoirs

### 6.1.1 Temperature

Temperature data collected prior to and during relicensing indicate that 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 fall. Some 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 locations farther upstream in the reservoir. In summer, solar heating increases the temperature of surface water in the reservoir well above that of the Skagit River inflow from May through November.

Despite elevated maximum temperatures near the surface of Ross Lake, there is a large volume of cold water in the reservoir throughout summer and fall. Although surface temperatures can be as high as 22°C (e.g., as recorded at Little Beaver in August, Figure 5.1-2), they are generally slightly lower with increasing distance downstream in the reservoir. However, cooler water persists at depth throughout the year at all locations (see Section 5.1.1).

Stratification also occurs in Diablo Lake near Diablo Dam, although summertime maximum temperatures are typically lower than those in Ross Lake given both the short residence time in Diablo Lake and moderate inflow temperatures of water withdrawn at depth in Ross Lake. Water temperatures in Diablo Lake generally remain below 16°C, and there is abundant cold water throughout the year (see Section 5.1.2). An exception to this pattern occurred in July 2021, when the surface temperature of Diablo Lake reached 24.5°C (Figure 5.1-28); this increase occurred following record-high air temperatures in the basin.

Gorge Lake does not stratify significantly due to its short residence time (less than 1 day), although minor vertical thermal gradients are observed during summer in the Gorge Dam forebay. Average daily water temperatures in Gorge Lake very rarely exceed 13°C, and temperature profile measurements show that conditions are nearly always vertically isothermal.

### 6.1.2 DO and pH

Vertical profiles of DO and pH in Ross Lake in 2022 and in Diablo and Gorge lakes in 2021 and 2022 show high levels of DO from surface to bottom with relatively minor changes in pH throughout the water column. Taken together, these results indicate low levels of primary production, a conclusion supported by nutrient and chlorophyll *a* measurements conducted concurrently.

### 6.1.3 Turbidity and TSS

Turbidity and TSS are typically low at all three Project reservoirs, with most values near or below laboratory detection limits. Monthly turbidity and TSS sampling at transects in the drawdown zone of Ross Lake and at Ross Lake tributary mouths showed that turbidity levels in Ross Lake and its tributaries remained low, except during runoff and snowmelt events. The highest turbidity levels within Ross Lake were observed at the international border (from the upper Skagit River) and at Ruby Creek. Transect sampling during drawdown in Thunder Arm in Diablo Lake also returned low levels of turbidity and TSS during all sampling events.

### 6.1.4 TDG

TDG monitoring in Gorge Lake indicates that both spill at Diablo Dam and, at times, operation of the Diablo Powerhouse may increase TDG levels in Gorge Lake. Discussion with City Light engineering staff indicates that operational effects on TDG observed in both 2021 and 2022 are likely due to an air admission system, designed to improve operating efficiency at low generation (Gordon 2021). Observed operational effects by Diablo Powerhouse were of limited duration, i.e., on the order of hours, and were not observed down-reservoir at the Gorge Dam forebay or downstream of Gorge Powerhouse.

Spill at Diablo Dam in 2022 caused elevated TDG (greater than 110 percent) in both upper Gorge Lake and at Gorge Dam forebay and the Gorge Powerhouse, which persisted from mid-January through most of April 2022. The Diablo Powerhouse was offline during trashrack repairs at Diablo Dam for a period that corresponded closely with measurements of elevated TDG at all three monitoring sites. Levels dropped quickly when the Diablo Powerhouse resumed operation and spill ceased in mid-April 2022.

### 6.1.5 Nutrients and Productivity

Nutrient and productivity monitoring conducted in 2022 show that levels of nitrogen, phosphorus, and organic carbon in the reservoirs and their tributaries were very low, typically below the laboratory PQL. Chlorophyll *a* and alkalinity were also low, reflecting low algal biomass and a poorly buffered, low ionic strength system. These findings are consistent with previous monitoring results and confirm that Project reservoirs are oligotrophic. Nutrient and productivity data appear to reflect natural background conditions and do not suggest Project-related effects.

As stated in Section 4.0, water quality data collected under the expanded program allow for the characterization of the trophic status of Project reservoirs. Based on criteria in the literature (e.g., Carlson 1977, Wetzel 2001), nutrients and chlorophyll *a* concentrations in Project reservoirs typically fall below thresholds defining oligotrophic conditions (based on average concentrations of 8 µg/L, 660 µg/L, 1.7 µg/L for phosphorus, nitrogen and chlorophyll *a*, respectively [Wetzel 2001]). Similarly, TP and chlorophyll *a* concentrations were typically below thresholds, i.e., 6 µg/L and 0.94 µg/L, respectively, identified as oligotrophic by the Carlson Trophic State Index (Carlson 1977). Based on chlorophyll *a*, the most accurate predictor of algal biomass (Carlson and Simpson 1996), Project reservoirs are oligotrophic.

### 6.1.6 Benthic and Drifting Macroinvertebrates

Ross Lake PONAR sampling showed that overall BMI abundance and taxa richness appeared to be lowest at Ruby Arm. BMI abundance and taxa richness varied among depth strata, a trend which was particularly apparent during the September 2022 sampling event. Abundance and taxa richness metrics tended to be highest in the upper varial zone, intermediate in the lower varial zone, and lowest in the permanently inundated zone. Aquatic oligochaete worms were the dominant taxa observed. Very few EPT taxa were observed at any sites or depth strata: in two of the three reported samples, EPT consisted of a single individual mayfly. Gatherers were the dominant functional group observed and generally accounted for more than 50 percent of the sample. The greatest functional group diversity was observed at shallow and intermediate depths in the upper and lower varial zones; little diversity was observed at permanently inundated sites.

PONAR sampling conducted in Diablo Lake indicates that BMI abundance and taxa richness were relatively consistent among sites during early summer, with most site-level variation observed during the September sampling event. Between June and September, abundance and taxa richness decreased at the Main Basin site, but both metrics increased at the Thunder Arm North and South sites. Across sites, midges, freshwater clams, and oligochaete worms were the dominant taxa observed. Similar to Ross Lake, very few EPT taxa were observed: all Diablo Lake samples that included EPT taxa contained a single individual. Gatherers were the dominant functional group observed in most samples, though filterers constituted a substantial proportion of June and August samples. In general, functional group diversity appeared to be higher in Diablo Lake than in Ross Lake.

Thunder Creek benthic kicknet data indicate that BMI abundance and taxa richness increased as the sampling season progressed. Kicknet samples contained a high proportion of EPT (greater than 85 percent) across sampling events, dominated by mayfly and stonefly taxa. Thunder Creek featured a diverse BMI functional group composition dominated by scrapers, gatherers, and predators, which remained consistent across sampling events.

Similar to benthic kicknet samples, drift sampling conducted at Thunder Creek indicated that invertebrate abundance and taxa richness increased as the sampling season progressed. Notably, abundance of drifting macroinvertebrates doubled between sampling events. All samples were dominated by a single chironomid (midge) taxon. Drift samples contained relatively few EPT taxa compared to benthic kicknet samples, ranging from 26-31 percent in drift samples and 87-93 percent in benthic samples. Functional group composition was similar across sampling events and dominated by gatherers, with notable proportions of predators, filterers, scrapers, and shredders.

Gorge Lake PONAR samples held far fewer macroinvertebrates than riverine sites; no benthic invertebrates were counted at the Gorge Lake site at the mouth of Stetattle Creek in June 2022. EPT taxa were also comparatively low, typically making up less than 10 percent of a sample. Dominant taxa present in the samples included nematodes, chironomids, and oligochaete worms.

Fewer functional groups were represented in Gorge Lake benthic samples than kicknet samples collected at Stetattle Creek. BMI identified were primarily gatherers, predators, or filterers. Month to month, group composition was most consistent at the deepest Gorge Lake site near Gorge Dam.

Taxa richness in Stetattle Creek was similar among the three monitoring events reported; 36-38 taxa were identified, less than the average of 44 taxa for sites downstream of Gorge Powerhouse (Section 5.3.8). Percent EPT composition for Stetattle Creek ranged from 71 percent in June 2022 to 49 percent in July 2022.

Functional group composition for Stetattle Creek in June was dominated by BMI classified as gatherers (32 percent) and scrapers (42 percent). Gatherers also dominated in July and August (49 percent and 37 percent, respectively). The most notable change in the BMI community at Stetattle Creek was the reduction in scrapers from June to July (12 percent) and August (19 percent), likely a function of greater biomass and/or quality of periphytic algae as a food source in early spring.

## 6.2 Gorge Bypass Reach and Gorge Powerhouse

Water temperature, DO, TDG, and turbidity were continuously monitored at three sites in the Gorge bypass reach from late January through October 2021. Temperatures at BYPASS1, near Gorge Dam, were warmer than other sites in the Gorge bypass reach, likely because of greater exposure to solar radiation and lack of flow (excluding periods of spill). Temperatures downstream at the Gorge Powerhouse, originating at depth from Gorge Lake, were cooler and less variable than those measured in the Gorge bypass reach.

Average DO concentrations over the 2021 reporting period were highest at Gorge Powerhouse (11.6 mg/L) and lowest at BYPASS2 (9.9 mg/L). DO at PHOUSE1 was generally higher; values remained above 9.5 mg/L, and concentrations demonstrated comparatively little variability. BYPASS2 was much more variable, but given comparatively late (due to supply issues) instrument deployment, data cannot be directly compared to other sites for the majority of the monitoring period.

TDG values at BYPASS1 reached 124 percent saturation during the approximately 7,300 cfs spill event at Gorge Dam in late June 2021. Analysis of spill and TDG during this period suggests that flows greater than 4,000 cfs result in TDG levels that exceed 110 percent in the bypass.

To evaluate the downstream extent of elevated levels of TDG, opportunistic monitoring during spill events downstream of Gorge Dam has been conducted at four locations: (1) Gorge Dam Access Bridge, (2) Gorge Powerhouse Access Bridge; and (3) two locations in the Skagit River downstream of Gorge Powerhouse, Ladder Creek Bridge, and the suspension bridge to Trail of the Cedars. TDG exceeded 110 percent saturation at the Gorge Dam Access Bridge (in the Gorge bypass reach) in July 2022 during a spill of 5,400 cfs but remained below 110 percent saturation in the Skagit River downstream of Gorge Powerhouse.

Turbidity in the Gorge bypass reach and below Gorge Powerhouse 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 rather than a reflection of ambient conditions. Turbidity at PHOUSE1 in 2022 was typically less than 5 NTUs, with occasional higher measurements that were less than 12 NTUs. Two events of elevated turbidity occurred in early August and mid-September of 2022. Both events were less than 70 NTUs.

The three sondes deployed in the Gorge bypass reach in 2021 were lost or damaged during extremely high flows in winter 2021, and no data are available for these locations after the October 5, 2021 site visit. High flows precluded access to the PHOUSE1 sonde until January 2022; however, the sonde was recovered and continuous monitoring is ongoing. Monitoring in the Gorge bypass reach transitioned to approximately monthly short-term (approximately 1 hour) deployments at BYPASS1 and BYPASS3; results of this monitoring have been consistent with continuous monitoring results from 2021.

## 6.3 Lower Skagit River

Water temperatures recorded at four sites in the Skagit River (i.e., SKAGIT2, 3, 4, and 5 at PRMs 91.6, 85.9, 75.6, and 69.3, respectively) remained below the 13°C (7-DADMax) salmon and trout spawning criterion from September 15 through June 15 in both 2020-2021 and 2021-2022, and below the 16°C (7-DADMax) core summer salmonid habitat criterion from June 16 through September 14 in 2021 and 2022.

In 2021, the 16°C core summer salmonid habitat criterion was exceeded at SKAGIT6 (PRM 60.8) in late August due to intermittent localized pooling at the deployment site. The 13°C salmon and trout spawning criterion was not exceeded upstream of PRM 69.3, i.e., not exceeded at sites SKAGIT2, 3, 4, and 5 at PRMs, 91.6, 85.9, 75.6, and 69.3, respectively, during the 2021-2022 data collection period.

SKAGIT9 (PRM 23.1), the farthest downstream monitoring site, and both Sauk River sites (SAUK1 and SAUK2), exceeded the 16°C core summer salmonid habitat criterion from the end of July 2022 through early September 2022. Water temperature monitoring is ongoing and will continue through May 2023.

DO in the Skagit River ranged from approximately 11 to 13 mg/L, with little diel fluctuation in June and greater fluctuation from July through September. DO saturation remained above 96 percent at all sampling sites and was usually at or above 100 percent. Maximum DO concentrations generally occurred during the afternoons upstream at SKAGIT3 and SKAGIT4, and in the evening or at night at SKAGIT7, possibly due to tributary influences, including the Baker River. pH values were generally between 7.0 and 7.5, with diel changes of 0.25 to 0.5 units. Diel variation in both DO and pH are indicative of dynamics associated with primary production.

Turbidity in grab samples collected in the Skagit River below the Project was less than 5 NTUs in all months and typically less than 2 NTUs in tributaries downstream of the Project, i.e., Newhalem Creek, and the Sauk and Baker rivers.

Nutrient concentrations in the Skagit River and its tributaries were very low (near or below the laboratory PQL), and chlorophyll *a* was typically less than 1 µg/L, consistent with results for the Project reservoirs (see above). Alkalinity was generally under 20 mg $CaCO_3$/L at all sites (maximum of 27.6 mg $CaCO_3$/L at the Sauk River in September), reflecting low ionic strength of the Skagit River and tributaries. Overall, water chemistry data indicate low productivity within the system.

Average taxa richness in benthic kicknet samples for all sites and sampling periods downstream of Gorge Dam was 44 taxa. With few exceptions, taxa richness was generally above 30 taxa for each sampling event and over 60 taxa in July 2022 at SKAGIT3X (PRM 85.6), within the Ross Lake National Recreation Area, and SKAGIT6X near Van Horn (PRM 59.7). Values were higher in July than during other months at most sites. Taxa richness was higher at each of the three side channels than their corresponding main channel sites, and generally relatively similar among main channel sites.

EPT composition was more variable than taxa richness and tended to decrease with distance downstream. Average percent EPT composition for all main channel sites during all visits was 35 percent. EPT taxa accounted for over 50 percent of identified taxa during all visits to SKAGIT5X (at Rockport, PRM 69.3). Average percent EPT composition was also over 50 percent at SKAGIT2X (near Newhalem, PRM 90.0) in samples collected in 2022 compared to 22 percent in August 2021. BMI classified as gatherers were most abundant in kicknet samples, and piercer herbivores least abundant.

Preliminary results of the intensive, transect sampling indicate that BMI abundance (number/$m^2$) was higher in the Skagit River main channel than in the Sauk River main channel (4 of 5 locations). However, percent EPT composition was consistently higher along the Sauk River than the Skagit River main channel transects. Little difference in taxa richness was seen between the Skagit and Sauk River sites among main channel samples. All three metrics (abundance, taxa richness, and percent EPT composition) were higher at the Skagit River side channel transects than the Sauk River side channel transects.

## 6.4 Status of June 9, 2021 Notice

The June 9, 2021 Notice included five items of discussion related to the implementation of the 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. | The CE-QUAL-W2 model of hydrodynamics and temperature has been developed and calibrated within the two-year timeframe for the simulation period of July 2019 through December 2020. The model has been used to evaluate the impact of cold-water releases from Ross Lake on temperature in the reservoirs and river downstream. The models are available to simulate other scenarios of interest.<br><br>Dr. Scott Wells has been retained as part of the City Light consultant team to act as an advisor for reservoir and river modeling.<br><br>City Light discussed CE-QUAL-W2 model development and calibration with LPs in a series of collaborative Water Quality Resource Work Group meetings that occurred between July 2021 and June 2022. |
| 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 Water Quality Monitoring Study QAPP, which is based on Ecology's Standard Operating Procedures, was included as an attachment to the Water Quality Monitoring Study RSP.<br><br>City Light submitted the provisional data summary to LPs on September 3, 2021. The full water quality data summary and analysis is provided as Attachment D to the FA-01a Water Quality Monitoring Study Interim Study Report (City Light 2022a). |
| 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.[11] | City Light has developed and implemented a sampling plan that provides the data needed to allow for the modeling of a range of water quality parameters, including nutrient dynamics, to address questions of productivity. City Light also substantially expanded the scope of its macroinvertebrate sampling (now including both 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 (downstream to the SR-9 Bridge). The sampling plan was informed by the content of NPS Appendix A and discussed with LPs extensively before adoption. |

[11] Taylor-Goodrich, K.F. Re: North Cascades National Park Service Complex comments on Seattle City Light's Revised Study Plan for the relicensing of the Skagit Project (No. 553), Appendix A. Letter to K.D. Bose, Secretary, Federal Energy Regulatory Commission, May 5, 2021.

| Study Modifications Identified in the June 9, 2021 Notice | Status |
|---|---|
| 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 will be initiated during the second year of study and completed prior to the filing of the Updated Study Report. | The modifications to the monitoring plan have occurred as described above. Development of the water quality model is underway. The FA-01b WQ Model Development Study report (City Light 2023a) documents hydrodynamic and temperature model development, calibration, and simulation results. The following tasks are in the process of being completed:<br>▪ Development and calibration of water quality (nutrients and productivity, in particular) models for the Project reservoirs and the Skagit River downstream of the Gorge Development.<br>▪ Application of the temperature and water quality models to evaluate potential flow management scenarios. |
| 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 convened the workshop as described and reached concurrence with LPs regarding an expanded sampling plan that allows for data collection to support the modeling of a range of water quality parameters, including nutrient dynamics to address questions of productivity. The plan addresses sampling frequency, monitoring locations, and temporal overlap with existing data. A plan describing the approach to collection of water quality data for use in the modeling was shared with LPs. |

# 7.0 VARIANCES FROM FERC-APPROVED STUDY PLAN AND PROPOSED MODIFICATIONS

The following subsections identify variances from the data collection approach outlined in the FERC-approved study plan. These changes are minor, affecting only a small fraction of the components of the overall sampling program. Despite these variances, City Light met the goals and the objectives of the study plan to characterize water quality conditions in Project reservoirs and the Skagit River downstream of the Project. Variances are presented under two subheadings: (1) those reported in the FA-01a WQ Monitoring Study Interim Report (City Light 2022a) and restated herein for completeness and (2) variances identified since the drafting of the FA-01a Interim Report.

## 7.1 List of Study Variances Reported in the FA-01a Interim Report

- Monthly water quality grab sampling (DO, pH, turbidity, and TSS) planned for the Skagit River in Canada was not conducted due to Covid-19-related travel restrictions. City Light is instead relying on data being collected by USGS in the upper Skagit River. The USGS data are being used for development and calibration of the CE-QUAL-W2 water quality model (City Light 2023a).
- The RSP called for turbidity measurements in Ross Lake to be monitored using *in situ* instrumentation. Turbidity was also analyzed in an analytical laboratory based on grab samples collected in the field. Results obtained from both methods are reported.
- Ross Lake turbidity and TSS transects, specified to be 100 m long in the RSP, were extended to 400 m for more complete representation of conditions at the sampling sites.
- In addition to FC sampling conducted per the RSP, *E. coli* samples were collected at Ross Lake Resort (ROSS8) during August 2021 and at all sites in Ross and Diablo lakes from September 2021 onward. *E. coli* was added to address a change in Washington State water quality standards [WAC 173-201A-200(2)(b)].
- Covid-19 related supply-chain impacts delayed the installation of datasondes used for long-term *in situ* monitoring in Gorge Lake, in the Gorge bypass reach, and below Gorge Powerhouse, postponing the start of data collection from June 2021 to July- September 2021, depending on the sampling site.
- The RSP indicates that BMI sampling was to occur in July and September 2021in the Skagit River. Sampling could not be conducted during either of the target months due to high flows. One set of samples was collected in August 2021. Subsequently, flows remained high, and suitable conditions for BMI sampling did not occur again in 2021, so the second sampling event did not take place (but a greatly expanded BMI sampling program was undertaken in 2022).
- Per the RSP, the SAUK1 temperature monitoring site was to be located at River Mile 2.8 in the Sauk River. However, the channel at this location is braided with dynamic shorelines. As a result, the thermograph was deployed at River Mile 5.4 where the channel is more stable and consistently wetted.

- Samples at the mouths of two tributaries to Ross Lake, Devil's Creek (TRIB6) and May Creek (TRIB7), were not sampled during the fall 2021 event. A logjam precluded access to the Devil's Creek site, and samples collected at the ROSS6 transect site were considered representative of conditions at May Creek.

## 7.2 Study Variances since Completion of the FA-01a Interim Report

Turbidity and TSS samples for Ross Lake were not collected at some sites during some months/seasons for the reasons identified in Table 7.2-1.

**Table 7.2-1. Sites/sampling periods in Ross Lake and its tributary mouths at which turbidity and total suspended solids samples were not collected according to the FERC-approved study plan.**

| Sampling Site | Sampling Month or Season Identified in the FERC-approved study plan | | |
|---|---|---|---|
| | **Nov/Dec 2021** | **January 2022** | **April 2022** |
| ROSS1 | Unsafe weather conditions | Unsafe weather conditions | Unsafe weather conditions |
| ROSS2 | Unsafe weather conditions | Unsafe weather conditions | Unsafe weather conditions |
| ROSS3 | Unsafe weather conditions | Unsafe weather conditions | Unsafe weather conditions |
| | **Fall 2021** | **Spring 2022** | |
| Silver Creek (TRIB2A) | Sampled per the study plan (no variance) | Streamflow was subterranean | |

Limited site access due to a closure of SR 20 precluded collection of monthly vertical profile data and turbidity and TSS samples at both Diablo and Gorge lakes in November 2021. Winter weather and unsafe conditions at Gorge Lake boat launches precluded collection of monthly samples at Gorge Lake sites in December 2021.

During fall 2021, sondes in the Gorge bypass reach were displaced during floods. Two of these units (BYPASS2 and BYPASS3) were lost, and the unit in the plunge pool below Gorge Dam (BYPASS1) was irreparably damaged. To reduce safety risks to field staff and avoid additional loss of equipment and data, short-term data gathering deployments began in 2022 in the Gorge bypass reach during baseflows and, opportunistically, during spill. Short-term deployments to collect baseline measurements occur at the BYPASS1 (below Gorge Dam in the plunge pool) and BYPASS3 (approximately 0.6 miles upstream of Gorge Powerhouse) locations.

Sample data from PHOUSE1 are unavailable for periods in 2022 due to dewatering of the sonde, equipment failure, and during periods when spill or other unsafe conditions prevented access, which resulted in battery loss.

The thermograph deployed at SKAGIT5 was lost in winter 2021 due to high flows and was replaced in July 2022. Short data gaps occur at SKAGIT4 due to dewatering of the thermograph, potentially as a result of stage fluctuations or members of the public pulling the thermograph from the water.

Additional water quality and macroinvertebrate monitoring beyond that prescribed in the FERC-approved study plan (i.e., expanded sampling program) has been conducted since May 2022 (and is ongoing). This monitoring includes commitments made by City Light in the June 9, 2021 Notice.

The expanded sampling program includes measurement of additional analytes and sampling at additional locations to support development and calibration of the CE-QUAL-W2 water quality model (FA-01b WQ Model Development Study, City Light 2023a). The expanded sampling program supplements ongoing water quality data collection to provide improved model boundary conditions for nutrients and organic matter entering reservoirs from the tributaries and additional model validation data within the reservoirs and the lower Skagit River. Sampling locations, frequencies, and parameters are described in Section 4 of this report.

The scope of macroinvertebrate monitoring included under the expanded sampling program is significantly larger than that identified in the FERC-approved study plan and includes reservoir and riverine benthic sampling and invertebrate drift data collection requested by LPs.

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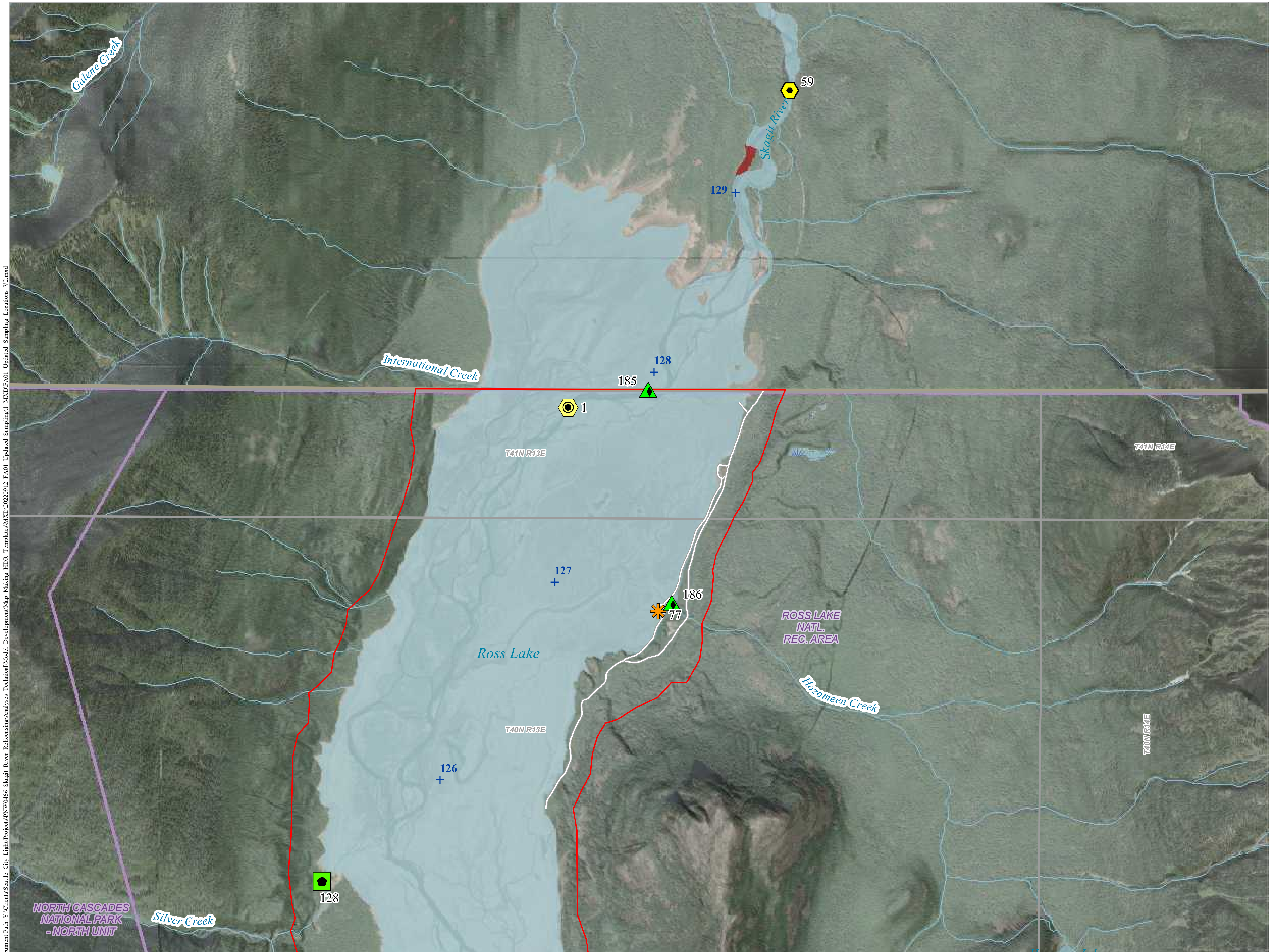
# WATER QUALITY MONITORING STUDY REPORT

# ATTACHMENT A

# WATER QUALITY SAMPLING LOCATIONS MAPBOOK

# FA-01 WQ MONITORING STUDY SAMPLING PROGRAM [ROSS - HOZOMEEN]




FERC Project Boundary

Project River Miles (PRM)

National Park / National Recreation Area Boundary

**Sampling Type**

Fall/Spring TSS & Turbidity (2x) & Monthly WQ Grab

BMI Kick/Drift (1x May)

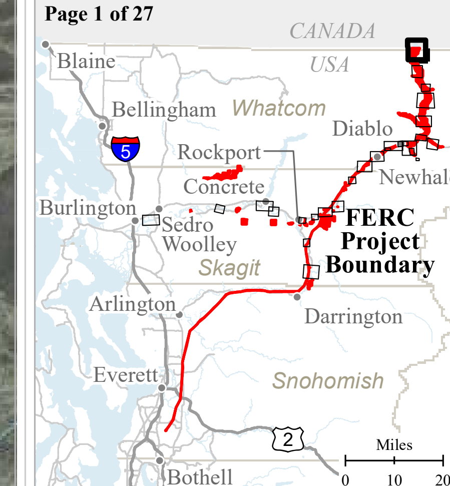
Fall/Spring TSS & Turbidity (2x) & Monthly WQ Grab & BMI Kick/Drift (1x May)

Monthly Fecal Coliform & E. coli

Monthly WQ Grab

0 1,100 2,200 Feet



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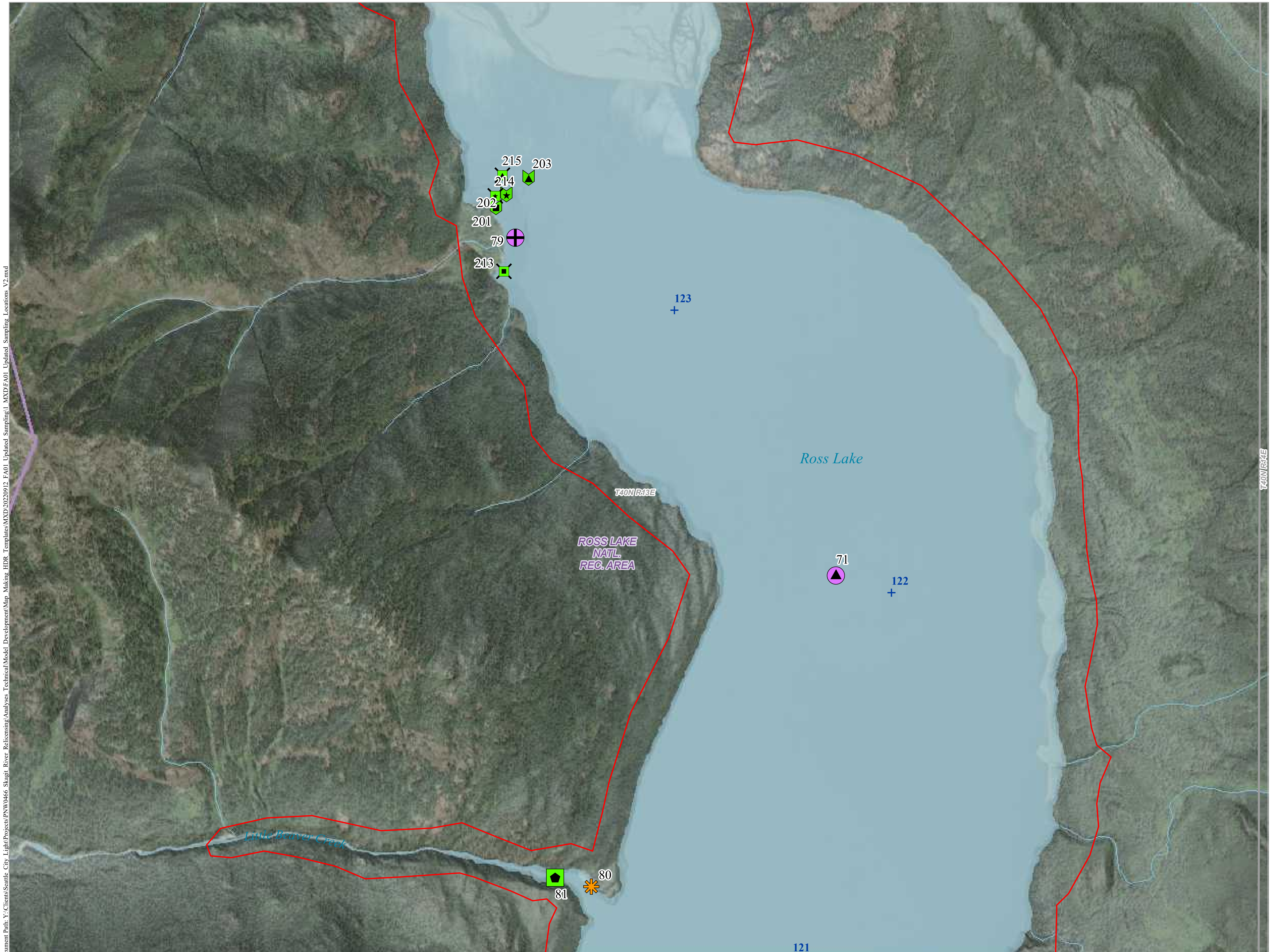



# FA-01 WQ MONITORING STUDY SAMPLING PROGRAM [ROSS - UPPER DESOLATION]

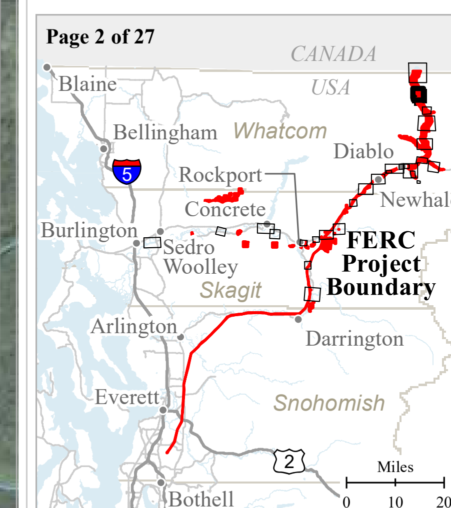
FERC Project Boundary
Project River Miles (PRM)
National Park / National Recreation Area Boundary

**Sampling Type**

- Inund Ponar
- LowVar Ponar
- HiVar Ponar
- LowVar Rock Basket
- Inund Rock Basket
- HiVar Rock Basket
- During Drawdown TSS & Turbidity Transect
- Fall/Spring TSS & Turbidity (2x) & Monthly WQ Grab & BMI Kick/Drift (1x May)
- Monthly TSS & Turbidity -1m and 5m
- Monthly Fecal Coliform & E. coli

N
0 690 1,380 Feet



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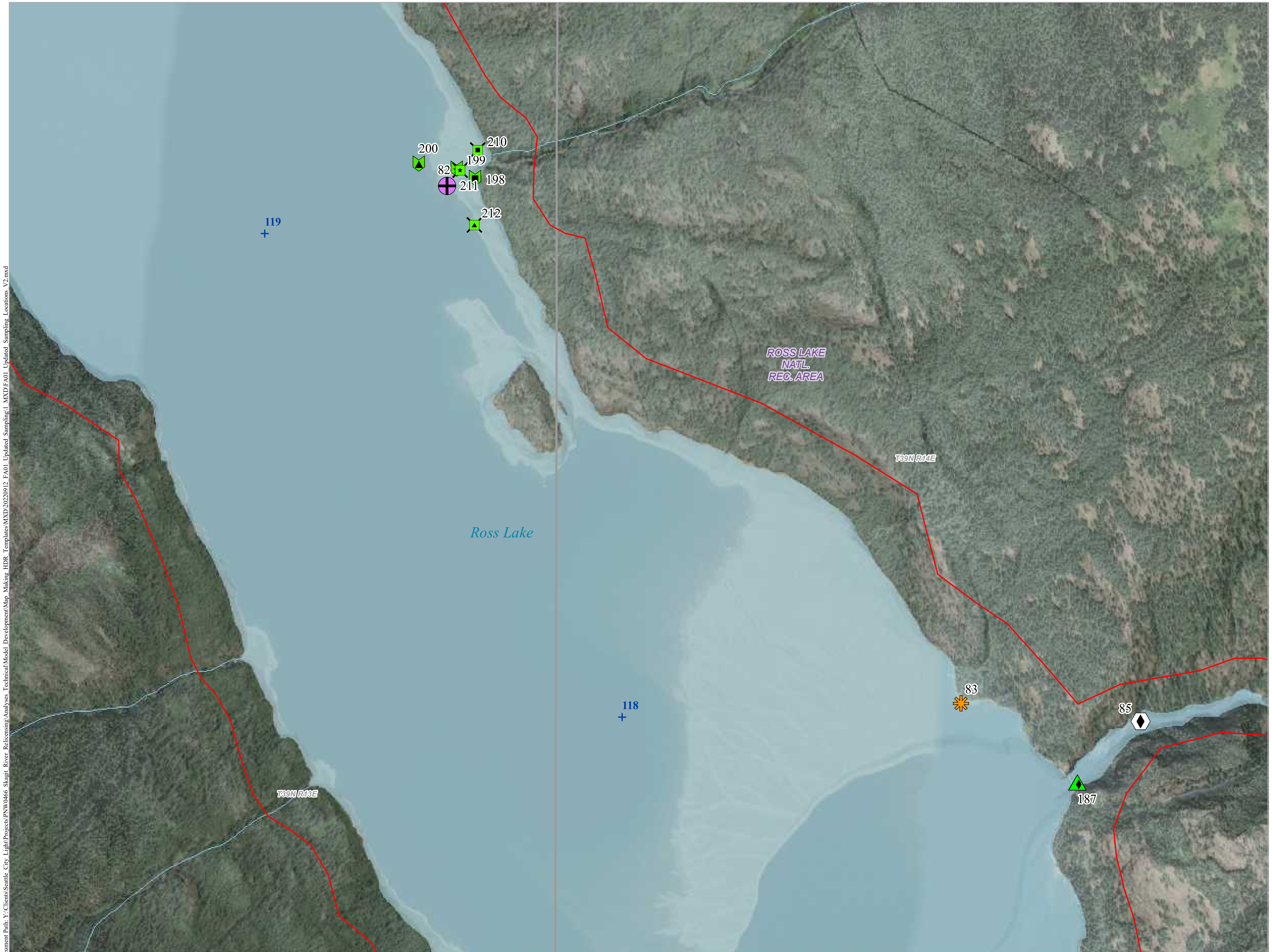



# FA-01 WQ MONITORING STUDY SAMPLING PROGRAM [ROSS - UPPER PUMPKIN]

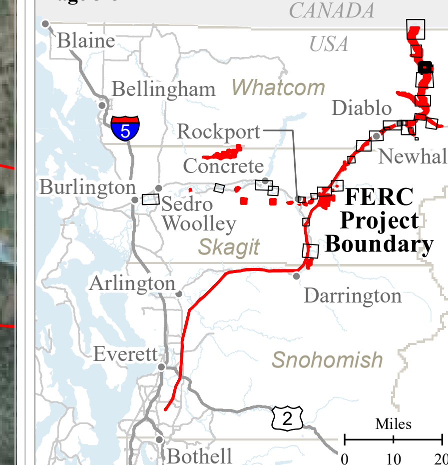
FERC Project Boundary
Project River Miles (PRM)
National Park / National Recreation Area Boundary

**Sampling Type**

Inund Ponar
LowVar Ponar
HiVar Ponar
LowVar Rock Basket
Inund Rock Basket
HiVar Rock Basket
Fall/Spring TSS & Turbidity (2x) & Monthly WQ Grab
BMI Kick/Drift (1x May)
During Drawdown TSS & Turbidity Transect
Monthly Fecal Coliform & E. coli

0 440 880 Feet



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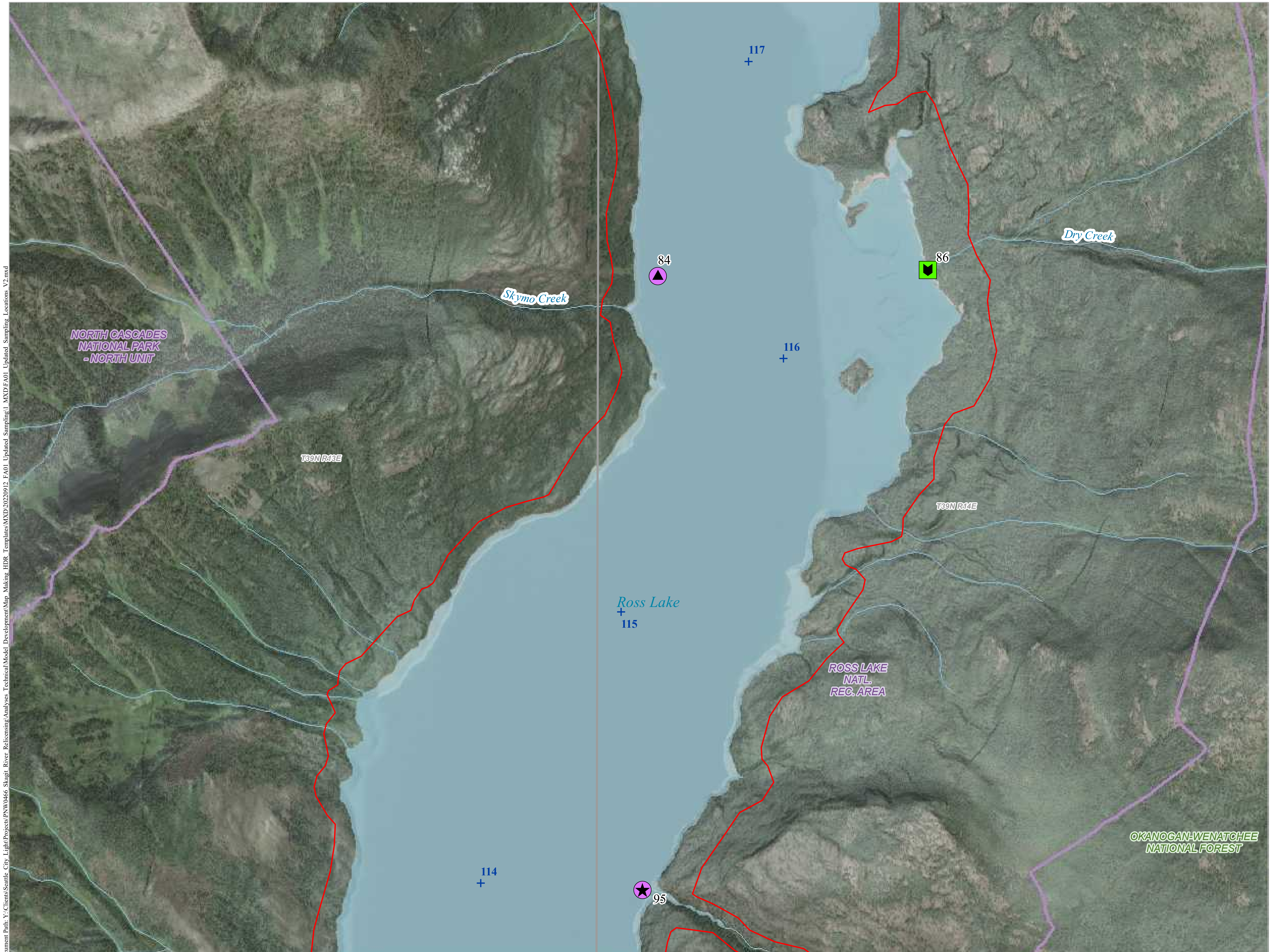



# FA-01 WQ MONITORING STUDY SAMPLING PROGRAM [ROSS - LOWER PUMPKIN]

- FERC Project Boundary
- Project River Miles (PRM)
- National Park / National Recreation Area Boundary

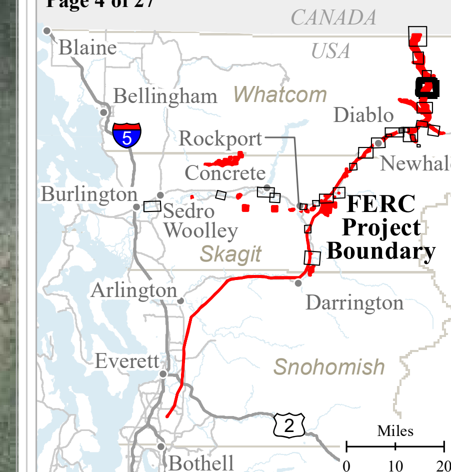
**Sampling Type**

- Fall/Spring TSS & Turbidity (2x) & BMI Kick/Drift (1x May)
- Fall/Spring TSS & Turbidity (2x)
- Monthly TSS & Turbidity -1m and 5m

N

0 860 1,720 Feet



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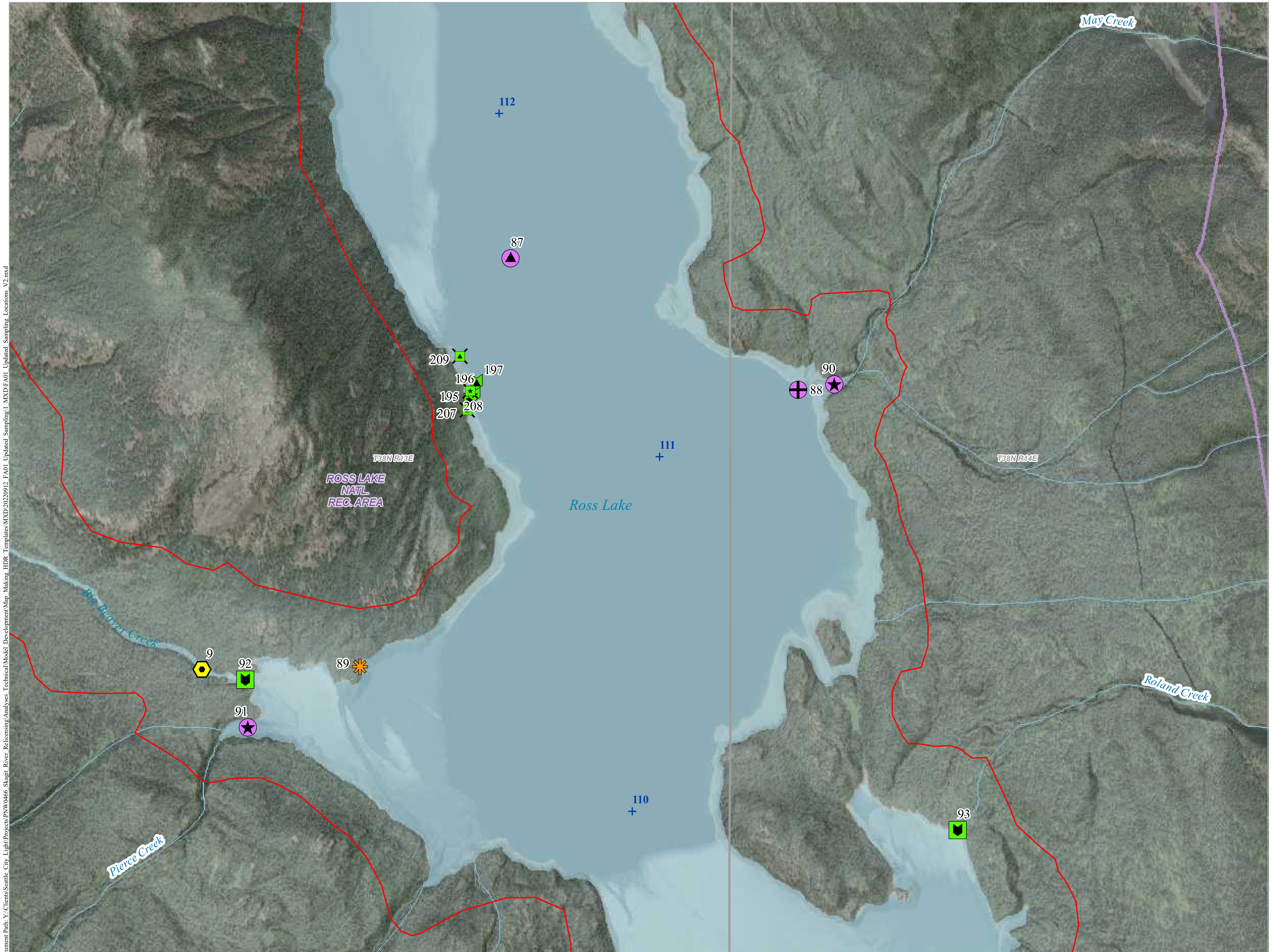
# FA-01 WQ MONITORING STUDY SAMPLING PROGRAM [ROSS - BIG BEAVER]



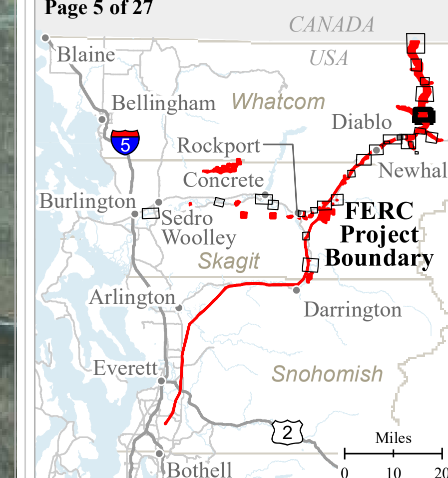

FERC Project Boundary
Project River Miles (PRM)
National Park / National Recreation Area Boundary

**Sampling Type**

Inund Ponar
LowVar Ponar
HiVar Ponar
LowVar Rock Basket
Inund Rock Basket
HiVar Rock Basket
During Drawdown TSS & Turbidity Transect
Fall/Spring TSS & Turbidity (2x) & BMI Kick/Drift (1x May)
Fall/Spring TSS & Turbidity
Monthly TSS & Turbidity -1m and 5m
Monthly Fecal Coliform & E. coli
Monthly WQ Grab

N
0 690 1,380 Feet



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# FA-01 WQ MONITORING STUDY SAMPLING PROGRAM [ROSS - FOREBAY AND RUBY]


FERC Project Boundary

Project River Miles (PRM)

National Park / National Recreation Area Boundary

**Sampling Type**

CT & Mon. TSS & Turb & Mon. Prof. (T DO pH) & 1x TDG

Inund Ponar

LowVar Ponar

HiVar Ponar

Monthy WQ Grab - 3 depths & Zooplanktion

LowVar Rock Basket

Inund Rock Basket

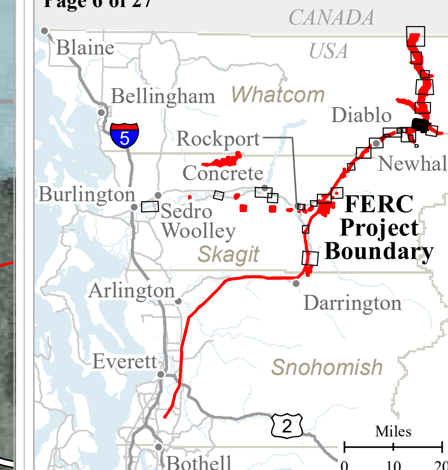
HiVar Rock Basket

Monthly Fecal Coliform & E. coli

N

0 500 1,000 Feet



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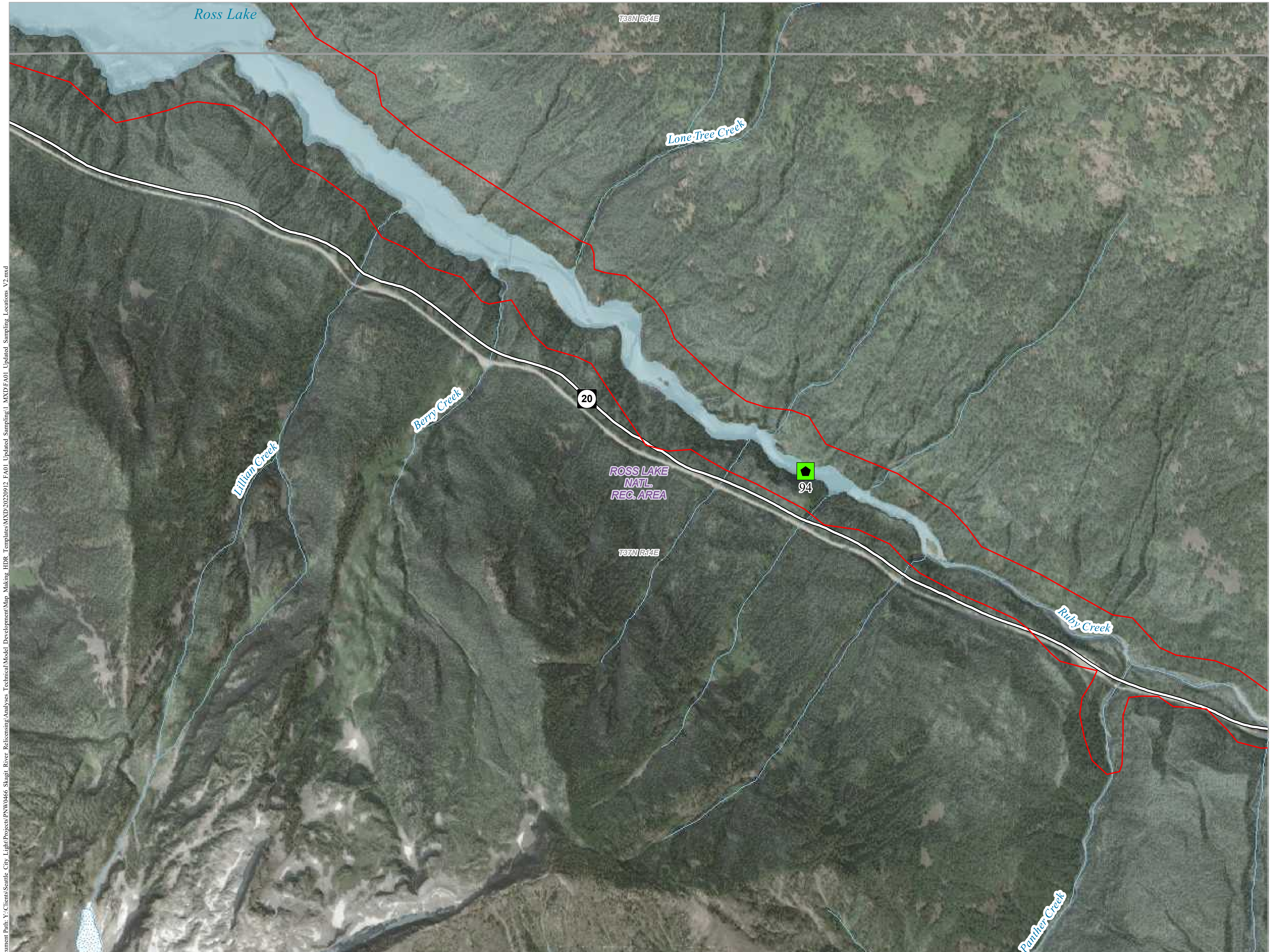
# FA-01 WQ MONITORING STUDY SAMPLING PROGRAM [ROSS - RUBY ARM]




FERC Project Boundary

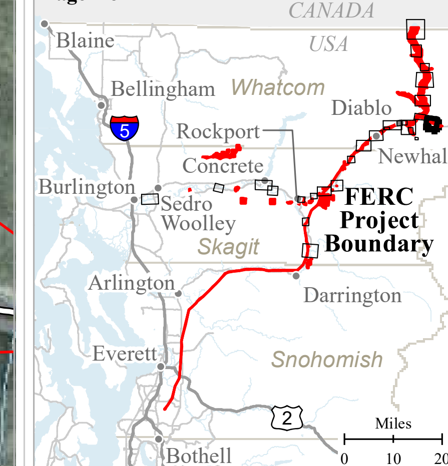
National Park / National Recreation Area Boundary

**Sampling Type**

Fall/Spring TSS & Turbidity (2x) & Monthly WQ Grab & BMI Kick/Drift (1x May)

0 660 1,320 Feet



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# FA-01 WQ MONITORING STUDY SAMPLING PROGRAM [DIABLO LAKE]

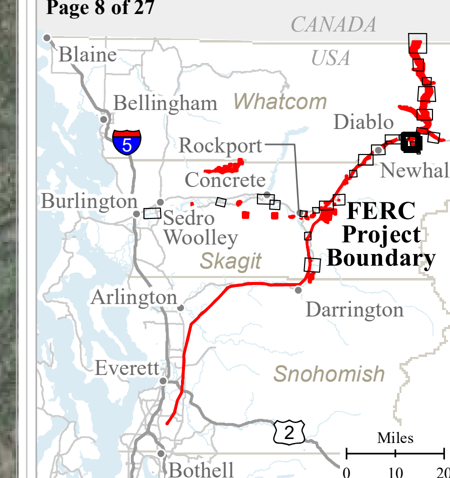

FERC Project Boundary
Project River Miles (PRM)
National Park / National Recreation Area Boundary

**Sampling Type**

- Inund Ponar
- Zooplankton
- BMI Ponar (6x Mar-Oct) & Zooplankton
- BMI Ponar (4x May-Oct)
- BMI Kick/Drift (4x May-Oct)
- CT & Monthly TSS & Turb & Monthly Profile (T DO pH)
- CT & Monthly WQ Grab - 3 depths & Monthly Profile (T DO pH SC)
- CT & Monthly WQ Grab
- Cont. TDG & Monthly TSS & Turb-1 and 5m & Mon. Prof. (T DO pH)
- During Drawdown TSS & Turbidity Transect
- Summer Monthly Fecal Coliform & E. coli

N
0 830 1,660 Feet



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**SKAGIT RIVER HYDROELECTRIC PROJECT (FERC NO. 553)**

# FA-01 WQ MONITORING STUDY SAMPLING PROGRAM [DIABLO - THUNDER NORTH AND SOUTH]


FERC Project Boundary

National Park / National Recreation Area Boundary

**Sampling Type**

Inund Ponar

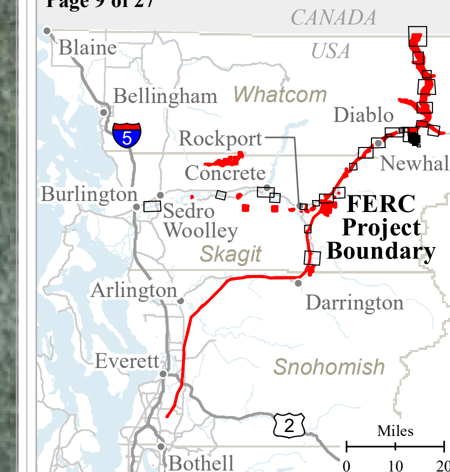
During Drawdown TSS & Turbidity Transect

Summer Monthly Fecal Coliform & E. coli

N

0 370 740 Feet



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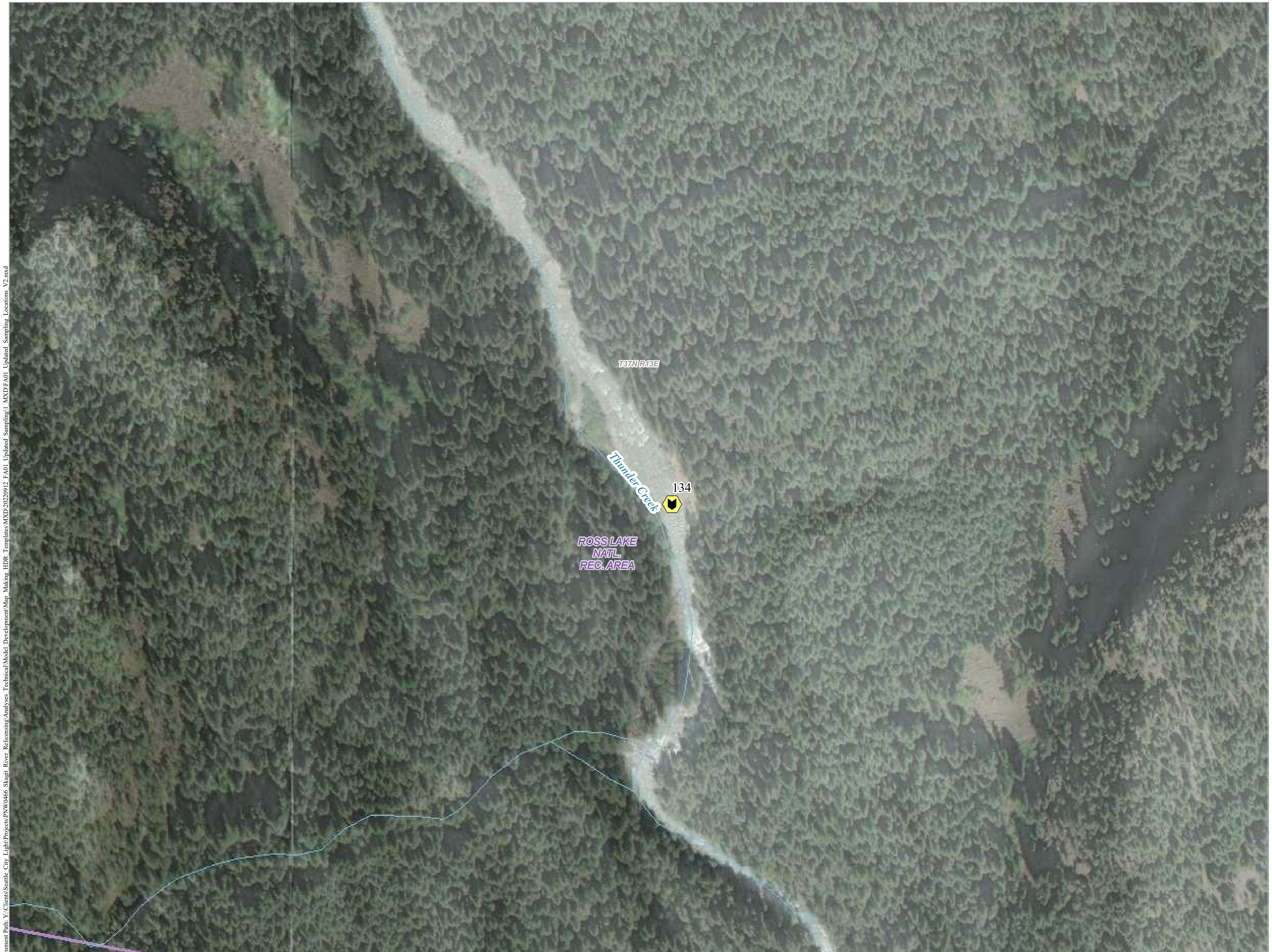
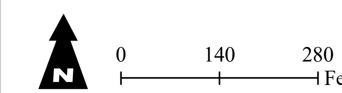



# FA-01 WQ MONITORING STUDY SAMPLING PROGRAM [DIABLO - OUTER THUNDER CREEK]

National Park / National Recreation Area Boundary

**Sampling Type**

CT & Monthly WQ Grab & BMI Kick/Drift (4x May-Oct )







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# FA-01 WQ MONITORING STUDY SAMPLING PROGRAM [DIABLO - DAM AND MAIN BASIN]

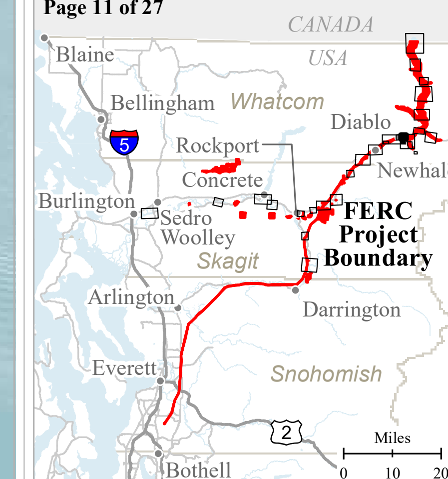
FERC Project Boundary
Project River Miles (PRM)
National Park / National Recreation Area Boundary

**Sampling Type**

CT & Monthly TSS & Turb & Monthly Profile (T DO pH)
CT & Monthly WQ Grab - 3 depths & Monthly Profile (T DO pH SC)
Summer Monthly Fecal Coliform & E. coli

0 250 500 Feet



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# FA-01 WQ MONITORING STUDY SAMPLING PROGRAM [STETATTLE CREEK]

FERC Project Boundary

Project River Miles (PRM)

National Park / National Recreation Area Boundary

**Sampling Type**

Zooplankton

BMI Ponar (6x Mar-Oct) & Zooplankton

BMI Ponar (4x May-Oct)

BMI Kick/Drift (4x May-Oct)

CT & Monthly TSS & Turb & Monthly Profile (T DO pH)

CT & Monthly WQ Grab - 3 depths & Monthly Profile (T DO pH SC)

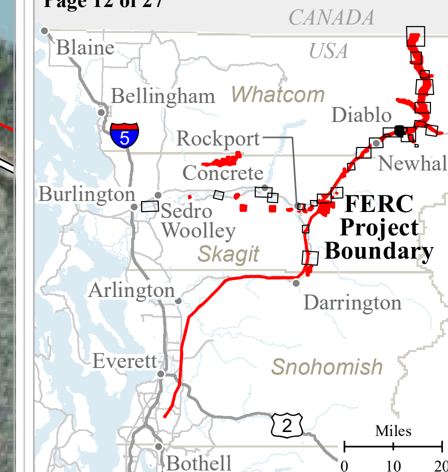
CT & Monthly WQ Grab

Cont. TDG & Monthly TSS & Turb-1 and 5m & Mon. Prof. (T DO pH)

N

0 280 560 Feet



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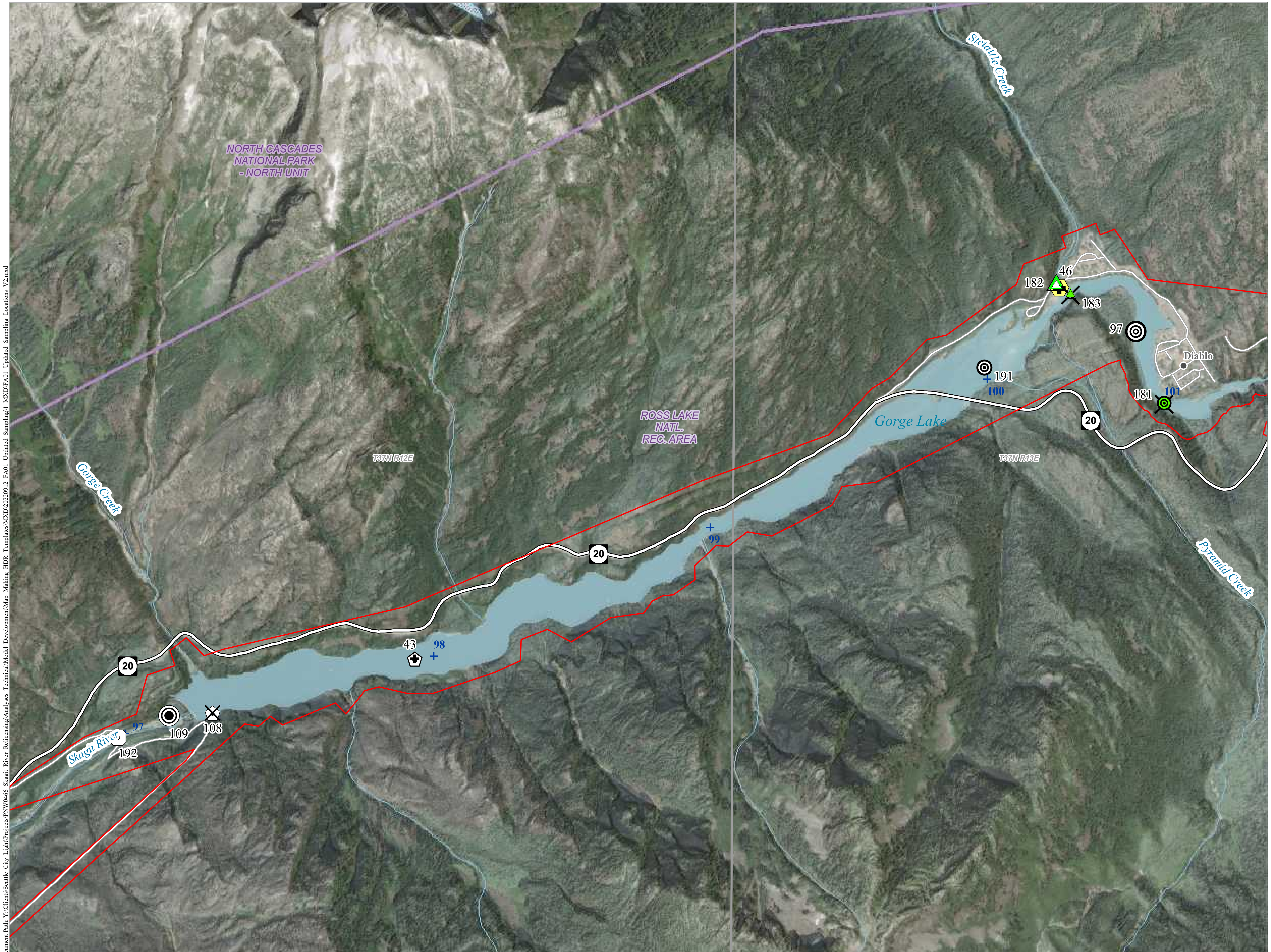
# FA-01 WQ MONITORING STUDY SAMPLING PROGRAM [GORGE LAKE]




- FERC Project Boundary
- Project River Miles (PRM)
- National Park / National Recreation Area Boundary

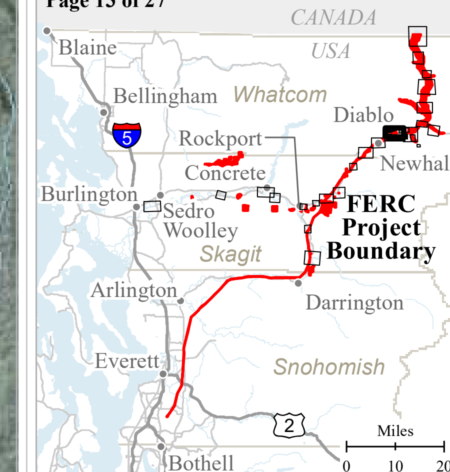
**Sampling Type**

- Episodic (T DO TDG Turb) Cont. TDG (Jan-Oct 2021)
- Zooplankton
- CT Profile & Zooplankton
- BMI Ponar (6x Mar-Oct) & Zooplankton
- BMI Ponar (4x May-Oct)
- CT & Cont. TDG & Mon WQ Grab & Mon Prof. ( T DO pH) & Ponar (6x Mar - Oct)
- BMI Kick/Drift (4x May-Oct)
- CT & Monthly WQ Grab
- Cont. TDG & Monthly TSS & Turb-1 and 5m & Mon. Prof. (T DO pH)
- During Spill TDG Grab

N

0 820 1,640 Feet



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# FA-01 WQ MONITORING STUDY SAMPLING PROGRAM [GORGE - WEST ZONE]

FERC Project Boundary

Project River Miles (PRM)

National Park / National Recreation Area Boundary

**Sampling Type**

Episodic (T DO TDG Turb) Cont. TDG (Jan-Oct 2021)

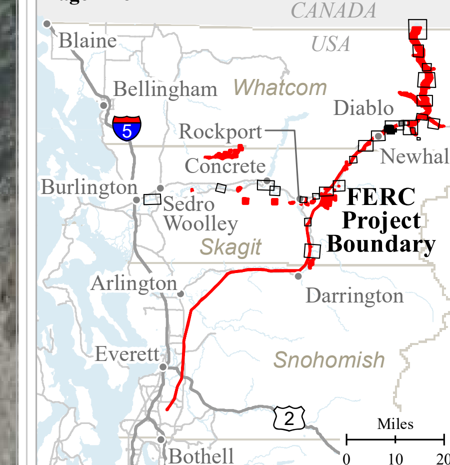
CT Profile & Zooplankton

CT & Cont. TDG & Mon WQ Grab & Mon Prof. ( T DO pH) & Ponar (6x Mar - Oct)

During Spill TDG Grab

0 230 460 Feet



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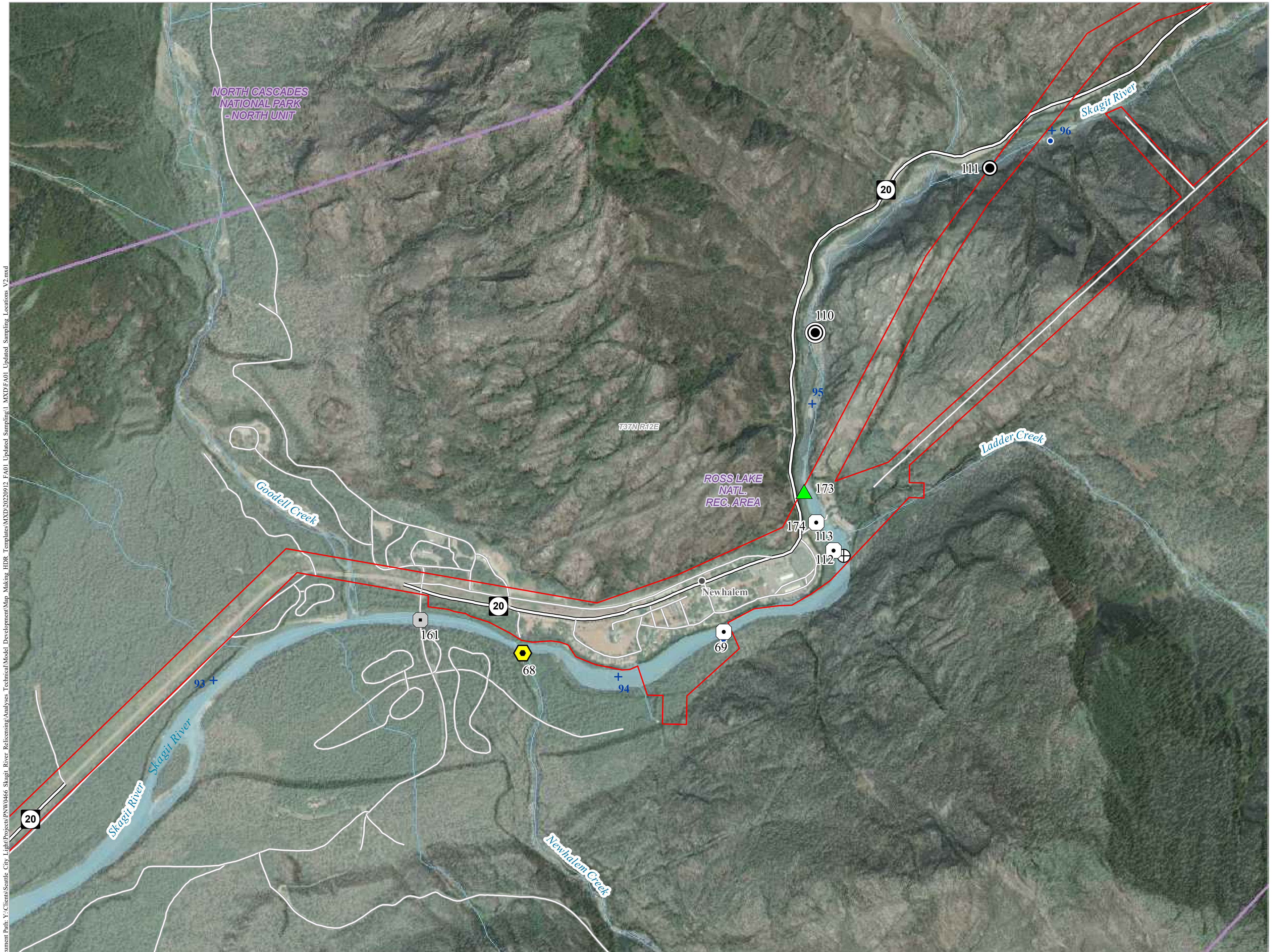



# FA-01 WQ MONITORING STUDY SAMPLING PROGRAM [GORGE BYPASS AND NEWHALEM]

FERC Project Boundary
Project River Miles (PRM)
Stream Gage (USGS)
National Park / National Recreation Area Boundary

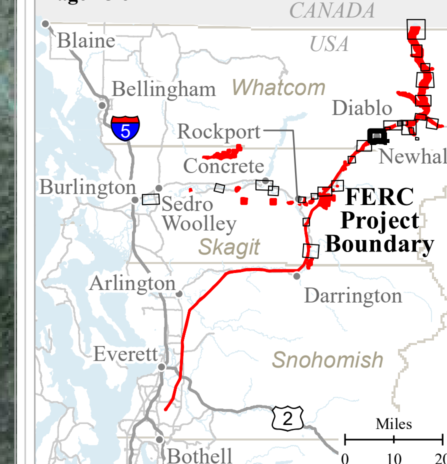
**Sampling Type**

Episodic (T DO TDG Turb) Cont. TDG (Jan-Oct 2021)
During Spill TDG Grab - Discontinued
Continuous (T DO TDG Turb pH) & Zooplankton & Periphyton
BMI Kick/Drift (4x May-Oct + 1 winter )
During Spill TDG Grab
Episodic (T DO TDG Turb)
Monthly WQ Grab

N

0 610 1,220 Feet



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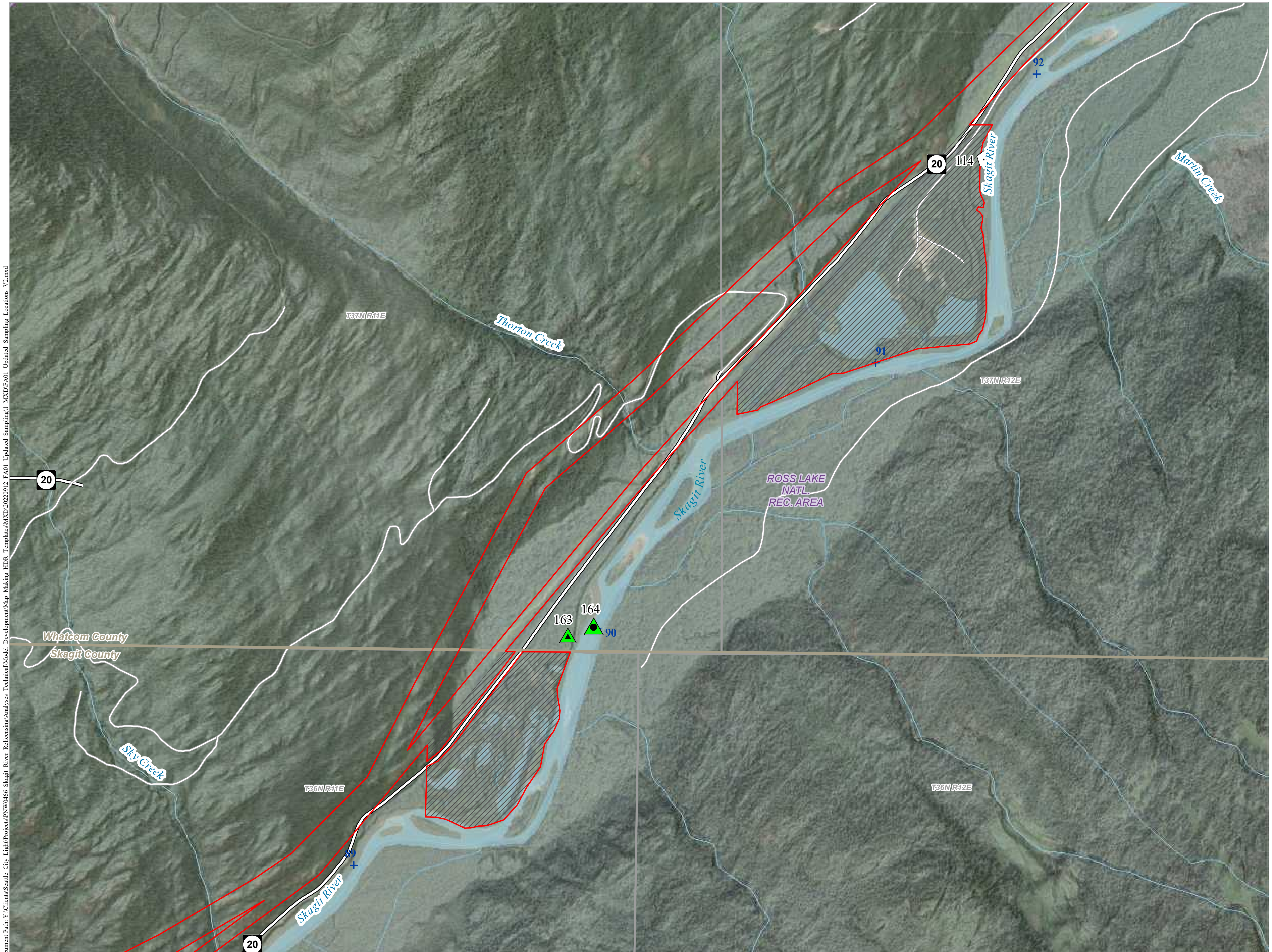


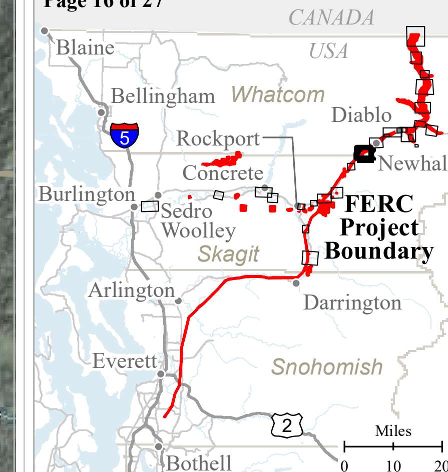

# FA-01 WQ MONITORING STUDY SAMPLING PROGRAM [BABCOCK TO SKY CREEK]

- FERC Project Boundary
- Mitigation Parcel
- Project River Miles (PRM)
- National Park / National Recreation Area Boundary

**Sampling Type**

- CT & BMI Kick Net (4x May-Oct + 1 winter )
- BMI Kick/Drift (4x May-Oct + 1 winter)
- CT

0 630 1,260 Feet

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# FA-01 WQ MONITORING STUDY SAMPLING PROGRAM [ALMA CREEK]

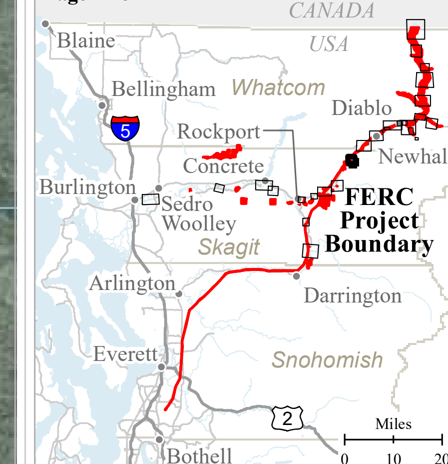
FERC Project Boundary
Project River Miles (PRM)
National Park / National Recreation Area Boundary

**Sampling Type**

BMI Kick/Drift (4x May-Oct)
CT & Flow & Monthy WQ Grab & Continuous WQ & Periphyton

0 375 750 Feet



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# FA-01 WQ MONITORING STUDY SAMPLING PROGRAM [CASCADE CONFLUENCE]

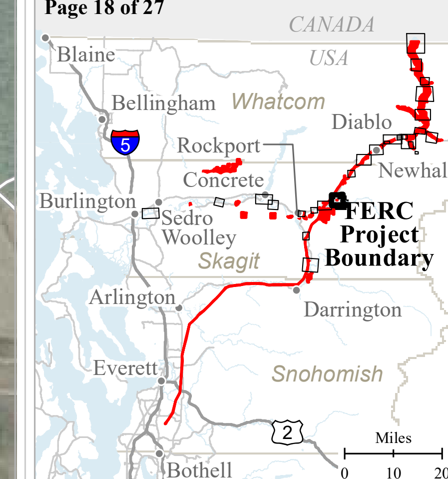
- FERC Project Boundary
- Mitigation Parcel
- Project River Miles (PRM)
- Stream Gage (USGS)

**Sampling Type**

- CT Flow & Monthly WQ Grab (Chl-a Alk Phyto)
- Monthly WQ Grab

0 610 1,220 Feet



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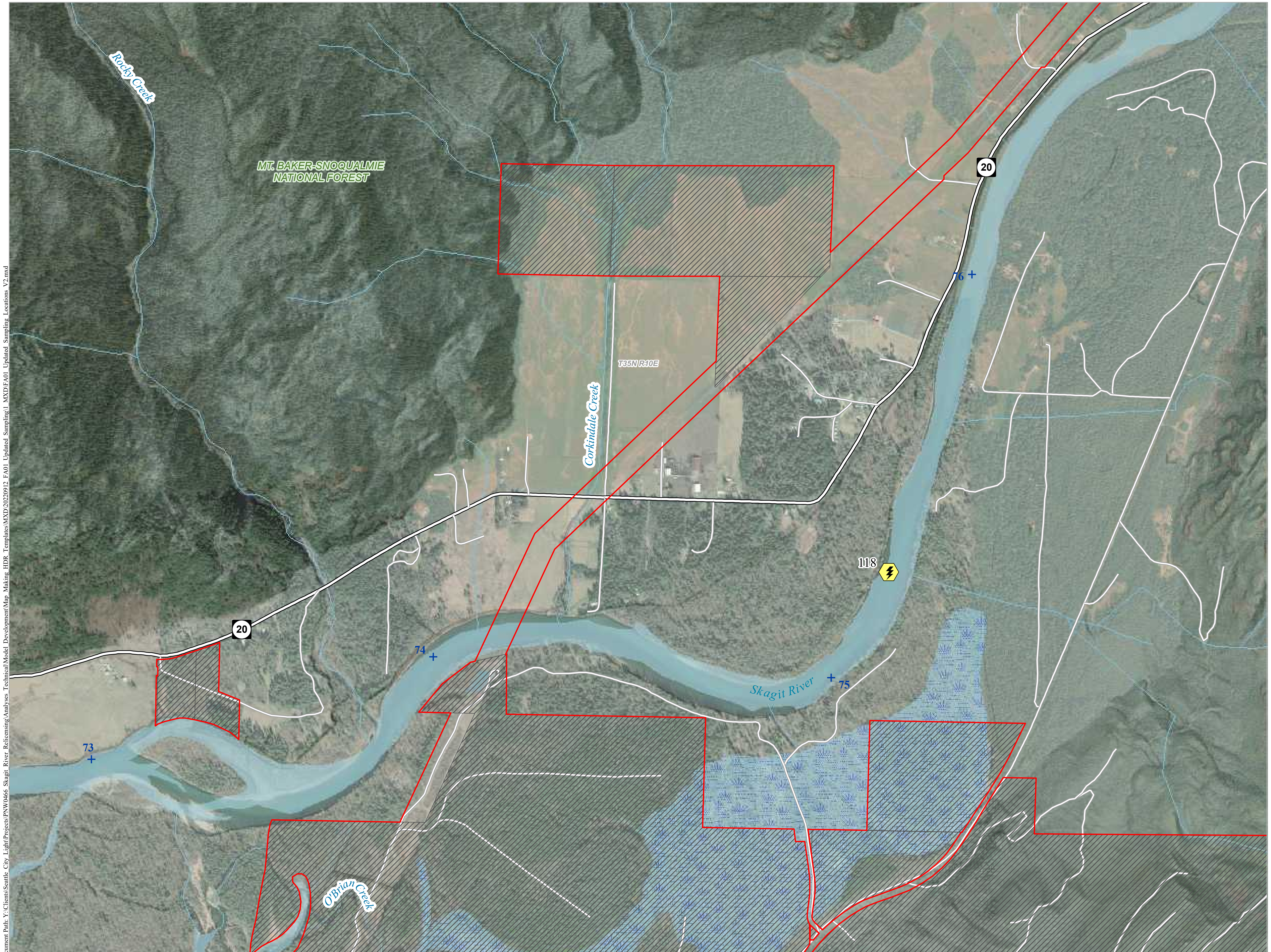
# FA-01 WQ MONITORING STUDY SAMPLING PROGRAM [CORKINDALE CREEK]




FERC Project Boundary

Mitigation Parcel

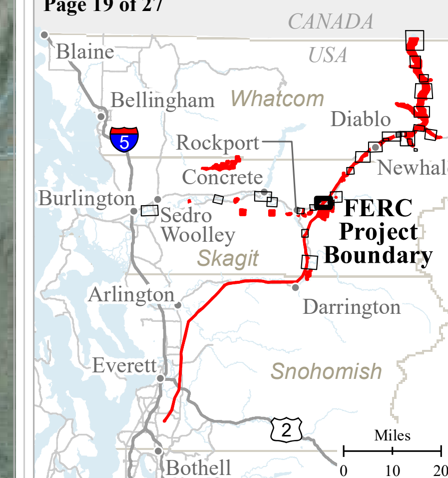
Project River Miles (PRM)

**Sampling Type**

CT & Monthly WQ Grab & Continous WQ & Periphyton

0 610 1,220 Feet



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# FA-01 WQ MONITORING STUDY SAMPLING PROGRAM [ILLABOT CREEK]


FERC Project Boundary

Mitigation Parcel

+ Project River Miles (PRM)

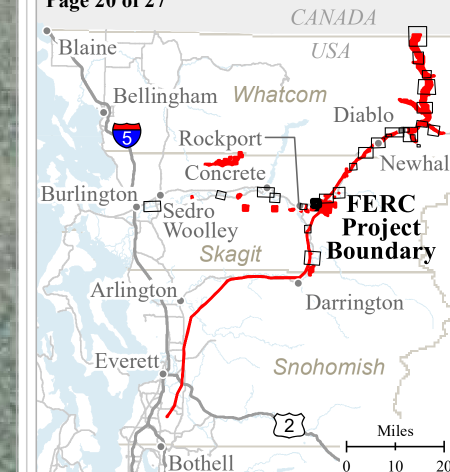
**Sampling Type**

Drift Net (4x May-Oct+ 1 winter)/Intensive Kick Net Transect

CT & BMI Ponar or Kick Net (4x May-Oct + 1 winter )

0 330 660 Feet



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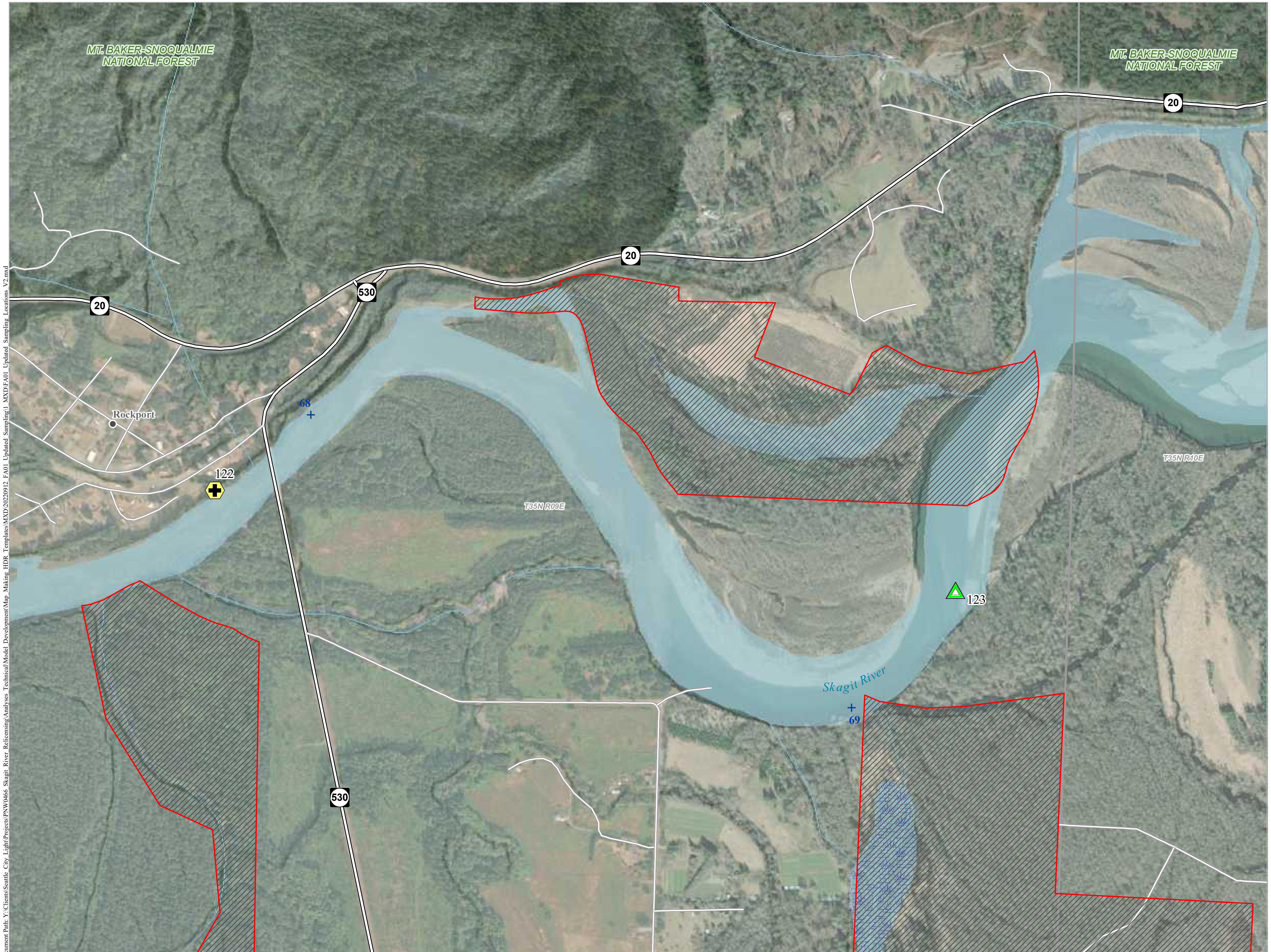
# FA-01 WQ MONITORING STUDY SAMPLING PROGRAM [MARBLEMOUNT]



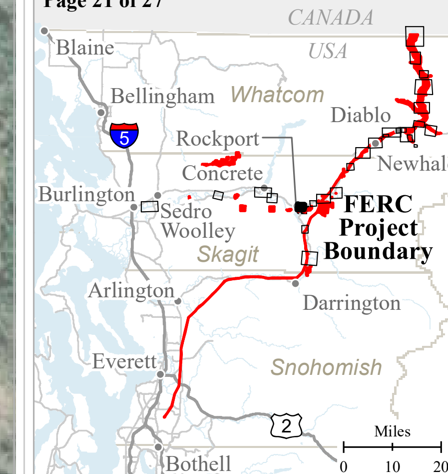

FERC Project Boundary
Mitigation Parcel
Project River Miles (PRM)

**Sampling Type**

BMI Kick/Drift (4x May-Oct)
CT & Monthly WQ Grab

0 330 660 Feet

Page 21 of 27

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# FA-01 WQ MONITORING STUDY SAMPLING PROGRAM [SAUK NORTH]

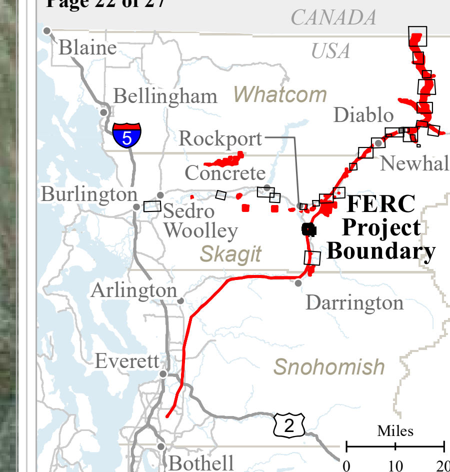
FERC Project Boundary
Stream Gage (USGS)

**Sampling Type**

BMI Kick/Drift (4x May-Oct)
CT & Monthly WQ Grab

0 450 900 Feet



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# FA-01 WQ MONITORING STUDY SAMPLING PROGRAM [SAUK SOUTH]


FERC Project Boundary

**Sampling Type**

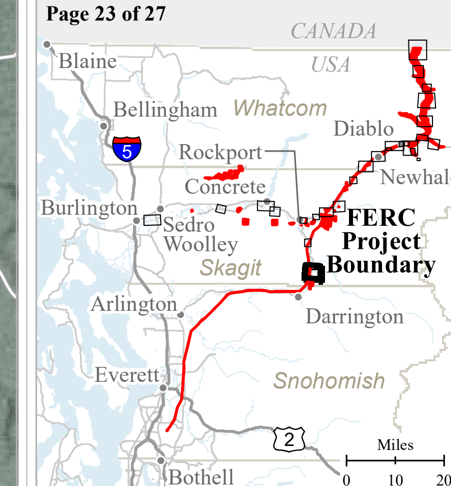
CT & BMI Intensive Kick Net

CT & BMI Intensive Kick Net Transect & Quarterly Nutrients

N

0 820 1,640 Feet

Page 23 of 27

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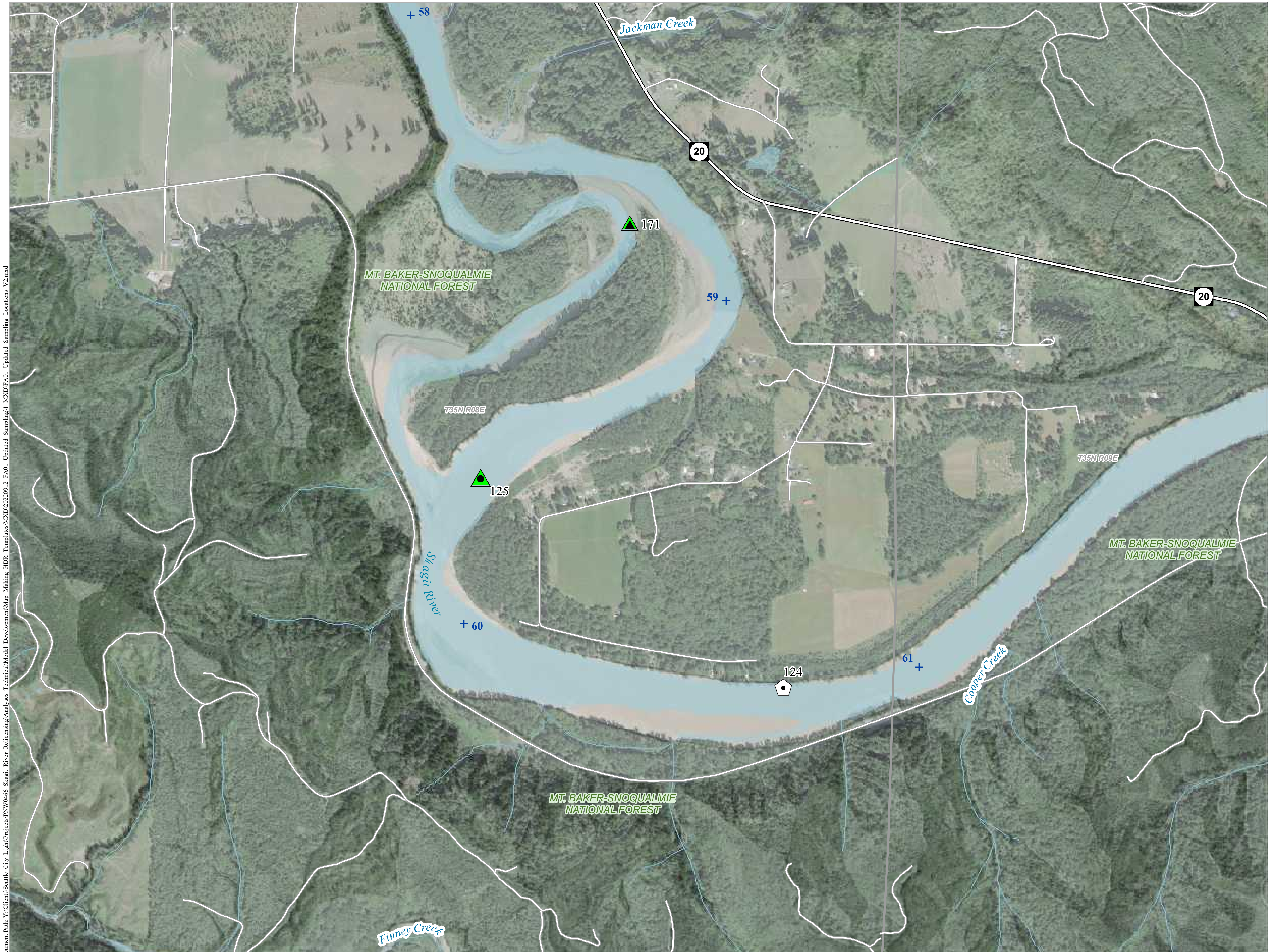



# FA-01 WQ MONITORING STUDY SAMPLING PROGRAM [COOPER TO JACKMAN CREEK]

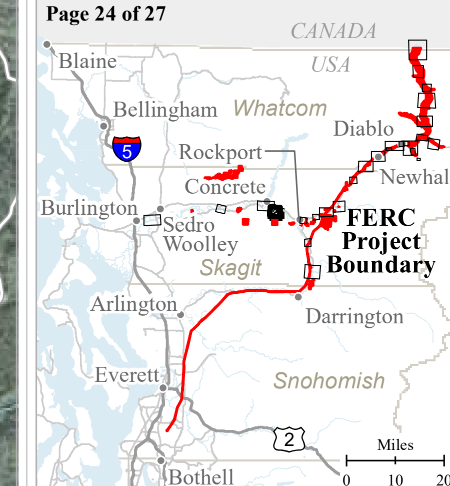
+ Project River Miles (PRM)

**Sampling Type**

- CT & BMI Kick Net (4x May-Oct)
- BMI Kick/Drift (4x May-Oct + 1 winter)
- CT

0 550 1,100 Feet



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# FA-01 WQ MONITORING STUDY SAMPLING PROGRAM [BAKER TO CONCRETE]


+ Project River Miles (PRM)
• Stream Gage (USGS)

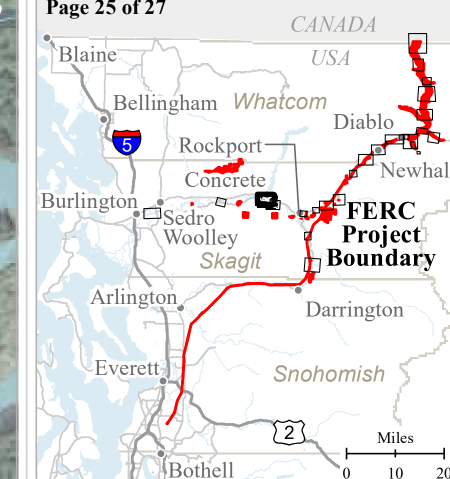
**Sampling Type**

- BMI Kick/Drift (4x May-Oct + 1 winter)
- BMI Kick/Drift (4x May-Oct)
- CT & Monthly WQ Grab & Continous WQ & Periphyton
- Monthly WQ Grab

N

0 740 1,480 Feet



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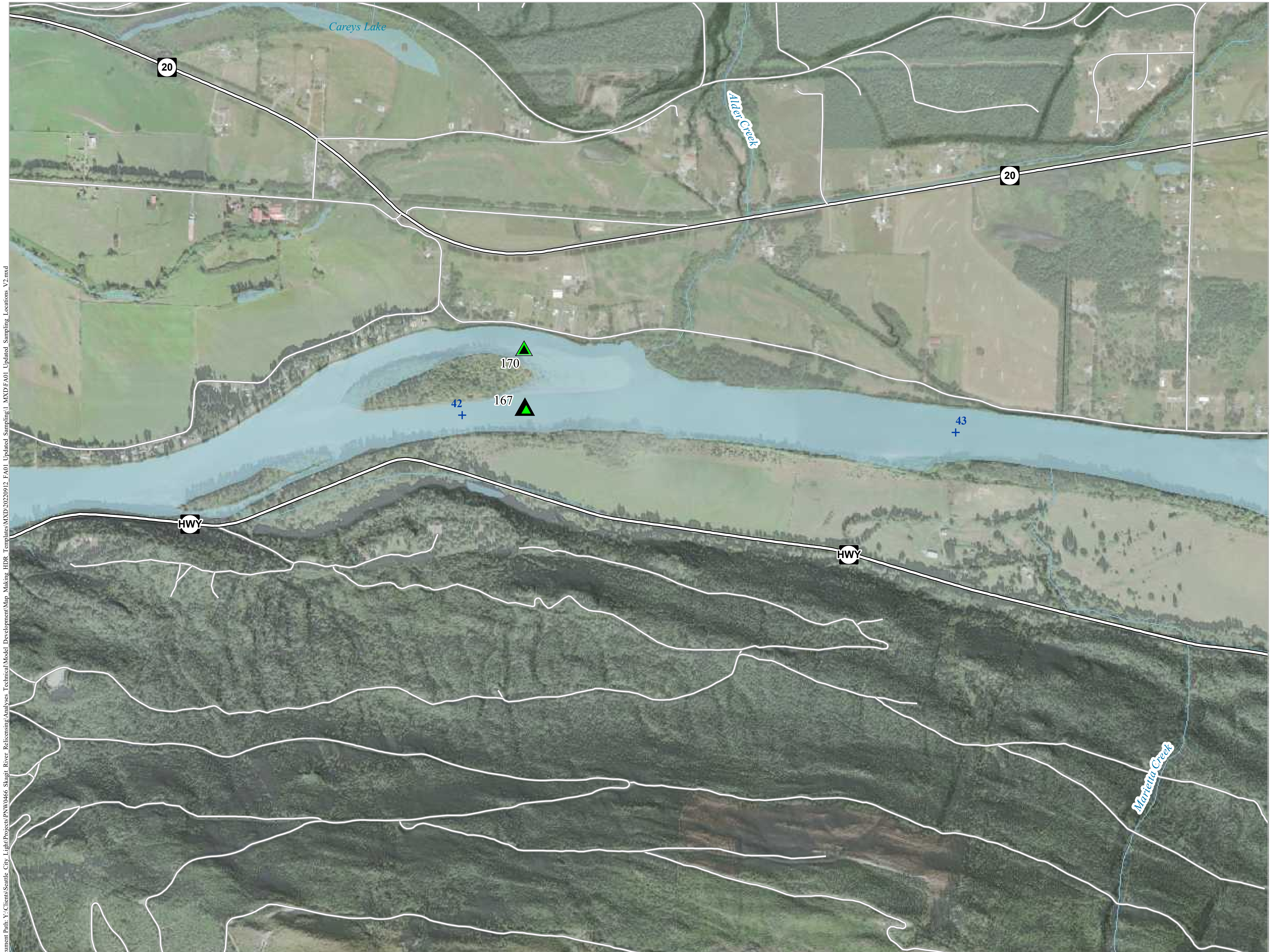
# FA-01 WQ MONITORING STUDY SAMPLING PROGRAM [ALDER CREEK]




+ Project River Miles (PRM)

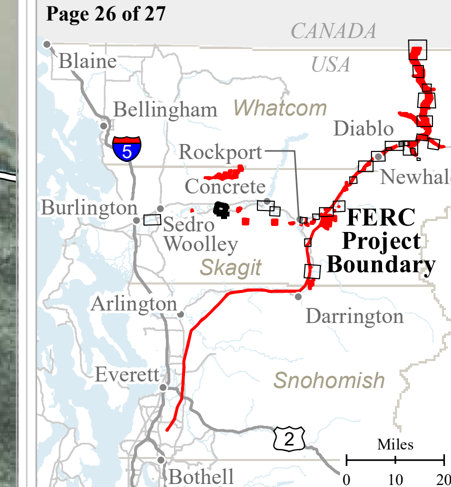
**Sampling Type**

- CT & BMI Kick Net (4x May-Oct)
- CT & BMI Kick/Drift (4x May-Oct)

N

0 530 1,060 Feet



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# FA-01 WQ MONITORING STUDY SAMPLING PROGRAM [SR-9 BRIDGE]


+ Project River Miles (PRM)

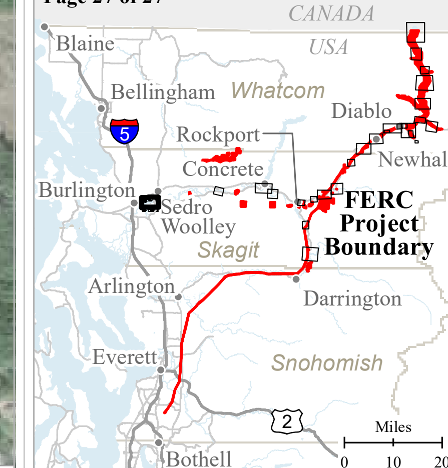
• Stream Gage (USGS)

**Sampling Type**

CT & BMI Kick/Drift (4x May-Oct)

0 740 1,480 Feet



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