

**FA-03 RESERVOIR FISH STRANDING AND TRAPPING
RISK ASSESSMENT**

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

Seattle City Light

**Prepared by:
Four Peaks Environmental Science & Data Solutions and
Blue Coast Engineering**

**March 2023
Updated Study Report**

TABLE OF CONTENTS

Section No.	Description	Page No.
1.0	Introduction.....	1-1
2.0	Study Goals and Objectives	2-1
3.0	Study Area	3-1
4.0	Methods.....	4-1
4.1	Reconnaissance Surveys	4-1
4.1.1	Ross Lake Reconnaissance	4-1
4.1.2	Opportunistic Diablo Lake Reconnaissance	4-4
4.2	Desktop Analysis	4-5
4.2.1	Analysis of DEMs for Potential Stranding and Trapping Risk Areas	4-5
4.2.1.1	Data Sources and Preparation	4-5
4.2.1.2	Geospatial Analyses.....	4-6
4.2.2	Analysis of Reservoir Drawdown.....	4-7
4.2.3	Integration of Reservoir Drawdown and GIS Analyses	4-8
4.2.4	Native Species Life Stage and Periodicity Analysis.....	4-9
4.2.5	Ross Lake Longitudinal Water Surface Elevation Profile.....	4-9
4.3	Sampling Design and Field Surveys	4-12
4.3.1	Ross Lake Sampling Design	4-12
4.3.1.1	Stratified Adaptive Cluster Sampling Process	4-13
4.3.1.2	Ross Lake 2021-2022 Field Survey Methodology	4-18
4.3.2	Diablo and Gorge Sampling Design	4-20
5.0	Results	5-1
5.1	Reconnaissance Surveys	5-1
5.1.1	Ross Lake Reconnaissance	5-1
5.1.1.1	December 2020 Ross Lake Survey	5-1
5.1.1.2	March 2021 Ross Lake Survey	5-1
5.1.1.3	April 2021 Ross Lake Survey	5-1
5.1.2	Opportunistic Diablo Lake Reconnaissance	5-2
5.1.3	Lessons Learned During Reconnaissance.....	5-2
5.1.3.1	Areas with High Potential for Stranding and Trapping	5-2
5.1.3.2	Refinements to Survey Methodology Based on 2020 and 2021 Reconnaissance Surveys	5-2
5.1.3.3	Logistics.....	5-3
5.1.3.4	Survey Timing	5-3
5.2	Desktop Analyses.....	5-4
5.2.1	Analysis of DEMs for Stranding and Trapping Risk.....	5-4

5.2.1.1	Ross Lake.....	5-4
5.2.1.2	Diablo and Gorge Lakes	5-7
5.2.2	Analysis of Reservoir Drawdown.....	5-13
5.2.2.1	Ross Lake.....	5-13
5.2.2.2	Diablo and Gorge Lakes	5-19
5.2.3	Integration of Reservoir Drawdown and GIS Analyses	5-30
5.2.3.1	Ross Lake.....	5-30
5.2.3.2	Diablo and Gorge Lakes	5-33
5.2.4	Native Species Life Stage and Periodicity Analysis.....	5-39
5.2.4.1	Background	5-39
5.2.4.2	Native Char	5-40
5.2.4.3	Rainbow Trout	5-41
5.3	Field Surveys	5-42
5.3.1	Ross Lake.....	5-42
5.3.2	Diablo and Gorge Lakes	5-46
5.4	Ross Lake Longitudinal Water Surface Elevation Profile.....	5-47
6.0	Discussion and Findings	6-1
6.1	Status of June 9, 2021 Notice	6-1
6.2	Interpretation of Findings	6-1
6.3	Integration of DEM, Drawdown, and Fish Periodicity Analyses	6-3
7.0	Variances from FERC-Approved Study Plan and Proposed Modifications.....	7-1
8.0	References	8-1

List of Figures

Figure No.	Description	Page No.
Figure 3.0-1.	Overview of study area.	3-2
Figure 4.1-1.	Ross Reservoir (i.e., Ross Lake) WSE from December 2020 through April 2021.....	4-2
Figure 4.1-2.	Ross Reservoir (i.e., Ross Lake) WSE at the time of each of the reconnaissance surveys: (A) December 17-18, 2020, (B) March 23-24, 2021, and (C) April 20-21, 2021.....	4-4
Figure 4.1-3.	Diablo Reservoir (i.e., Diablo Lake) WSE during mid-September 2020.	4-5
Figure 4.2-1.	Scheme of a run of river hydropower plant showing longitudinal section from the dam to the head of the reservoir (bottom).	4-9
Figure 4.2-2.	Longitudinal profile of model-predicted water surface elevations within John Day Reservoir (Columbia River) under differing operational scenarios.....	4-10

Figure 4.2-3.	Cross-sectional profiles at locations within John Day Reservoir (Columbia River), showing the range of water surface elevation under three drawdown scenarios.....	4-11
Figure 4.3-1.	Process diagram for identification of stratified randomized sampling starting locations.	4-13
Figure 4.3-2.	Area around mouth of Big Beaver Creek, showing overlaid 25-meter quadrats that are each assigned an alphanumeric identifier.....	4-14
Figure 4.3-3.	Area around mouth of Big Beaver Creek, showing overlaid quadrats, color coded by potential stranding and trapping group as determined from GIS-analyses. Contour lines indicate projected WSE for a potential field survey. Cells are colored based on the count of different types of features they contain.....	4-15
Figure 4.3-4.	Example WSE (feet above CoSD) plot at Ross Dam evaluated to estimate the rate of WSE change (USGS 2022a).....	4-16
Figure 4.3-5.	Area around mouth of Big Beaver Creek, showing overlaid quadrats, color coded by potential stranding and trapping group as determined from GIS-analyses. Contour lines indicate projected WSE for a potential field survey.	4-17
Figure 4.3-6.	Ross Reservoir (i.e., Ross Lake) WSE from October 2021 through September 2022.	4-19
Figure 4.3-7.	Survey data field form for use with tablet or mobile device.....	4-20
Figure 4.3-8.	Diablo Reservoir (i.e., Diablo Lake) WSE from May through October 2021.	4-21
Figure 4.3-9.	Gorge Reservoir (i.e., Gorge Lake) WSE from May through October 2021.....	4-21
Figure 5.2-1.	Overview map of surveys conducted around Ross Lake, displaying low slope and sink areas.	5-5
Figure 5.2-2.	Ross Lake low slope area in acres (ac) by elevation.	5-6
Figure 5.2-3.	Ross Lake sink area in acres (ac) by elevation.	5-7
Figure 5.2-4.	Diablo Lake overview of survey locations, displaying low slope and sink areas in Thunder Arm.	5-8
Figure 5.2-5.	Diablo Lake Thunder Arm low slope area in acres (ac) by elevation.	5-9
Figure 5.2-6.	Diablo Lake Thunder Arm sink area in acres (ac) by elevation.	5-10
Figure 5.2-7.	Gorge Lake overview of survey locations, displaying low slope and sink areas.	5-11
Figure 5.2-8.	Gorge Lake low slope area in acres (ac) by elevation.	5-12
Figure 5.2-9.	Gorge Lake sink area in acres (ac) by elevation.	5-13
Figure 5.2-10.	Ross Lake WSE time series (2011 to 2021).	5-14
Figure 5.2-11.	Frequency of occurrence and exceedance for hourly WSE records at Ross Lake (2011 to 2021).....	5-16
Figure 5.2-12.	Frequency of occurrence and exceedance for hourly WSE records during the month of January at Ross Lake (2011 to 2021).	5-17

Figure 5.2-13. Ross Lake drawdown event duration for all drawdown events (2011 to 2021).	5-18
Figure 5.2-14. Ross Lake drawdown event duration for drawdown events less than or equal to 24 hours duration (2011 to 2021).	5-18
Figure 5.2-15. Diablo Lake WSE time series (2011 to 2021).	5-20
Figure 5.2-16. Gorge Lake WSE time series (2011 to 2021).	5-21
Figure 5.2-17. Frequency of occurrence and exceedance for hourly WSE records at Diablo Lake (2011 to 2021).	5-23
Figure 5.2-18. Frequency of occurrence and exceedance for hourly WSE records at Gorge Lake (2011 to 2021).	5-24
Figure 5.2-19. Time series of drawdown events at Diablo Lake for a rim elevation of 1,206 feet NAVD 88 (2011 to 2021).	5-26
Figure 5.2-20. Time series of drawdown events at Gorge Lake for a rim elevation of 876 feet NAVD 88 (2011 to 2021).	5-27
Figure 5.2-21. Diablo Lake drawdown event duration for all drawdown events (2011 to 2021).	5-28
Figure 5.2-22. Diablo Lake drawdown event duration for drawdown events less than or equal to 24 hours duration (2011 to 2021).	5-28
Figure 5.2-23. Gorge Lake drawdown event duration for all drawdown events (2011 to 2021).	5-29
Figure 5.2-24. Gorge Lake drawdown event duration for drawdown events less than or equal to 24 hours duration (2011 to 2021).	5-29
Figure 5.2-25. Monthly Ross Lake drawdown event counts (2011 to 2021) multiplied by low slope area in the upper 50 percent water surface elevation percentile.	5-31
Figure 5.2-26. Monthly Ross Lake drawdown event counts (2011 to 2021) multiplied by sink area in the upper 50 percent water surface elevation percentile.	5-32
Figure 5.2-27. Monthly Diablo Lake drawdown event counts (2011 to 2021) multiplied by low slope area within the varial zone.	5-34
Figure 5.2-28. Monthly Diablo Lake drawdown event counts (2011 to 2021) multiplied by sink area within the varial zone.	5-35
Figure 5.2-29. Monthly Gorge Lake drawdown event counts (2011 to 2021) multiplied by low slope area across frequently dewatered elevation bands.	5-37
Figure 5.2-30. Monthly Gorge Lake drawdown event counts (2011 to 2021) multiplied by sink area across frequently dewatered elevation bands.	5-38
Figure 5.2-31. Monthly use by native char and Rainbow Trout within Ross, Diablo, and Gorge lakes.	5-39
Figure 5.3-1. Ross Reservoir (i.e., Ross Lake) WSE (feet above CoSD) at the time of field surveys on October 5, 2021 (A), October 26-27, 2021 (B), April 5-6, 2022 (C), and September 16, 2022 (D) (USGS 2022a). Shaded rectangular boxes indicate approximate periods of reconnaissance surveys.	5-43

Figure 5.3-2.	Diablo Reservoir (i.e., Diablo Lake) WSE (feet above CoSD) at the time of field surveys on May 10, 2022 (A), June 30, 2022 (B), September 1, 2022 (C), and October 26, 2022 (D, USGS 2022b).....	5-46
Figure 5.3-3.	Gorge Reservoir (i.e., Gorge Lake) WSE (feet above CoSD) at the time of field surveys on May 10, 2022 (A), June 30, 2022 (B), August 30, 2022 (C), and October 26, 2022 (D, USGS 2022c).	5-47
Figure 5.4-1.	Reference map of Ross Lake (left panel), plotted alongside the water's edge location (latitude) and water surface elevation (WSE) during three field surveys. Vertical orange lines in panels for each survey indicate the reference WSE as measured at Ross Dam (USGS Gage 12175000). Field WSE was calculated using DEM elevation at the water's edge location recorded in the field.	5-48
Figure 6.3-1.	Stranded fish observations at the mouth of Colonial Creek during the October 2022 survey of Diablo Lake.....	6-5

List of Tables

Table No.	Description	Page No.
Table 5.2-1.	Ross Lake potential stranding (low slope) and trapping (sink) areas by WSE percentile.....	5-6
Table 5.2-2.	Diablo Lake potential stranding (low slope) and trapping (sink) areas by WSE percentile.	5-9
Table 5.2-3.	Gorge Lake potential stranding (low slope) and trapping (sink) areas by WSE percentile.	5-12
Table 5.2-4.	Ross Lake WSE statistics (2011 to 2021).....	5-13
Table 5.2-5.	Ross Lake WSE (feet NAVD 88) statistics by month of year based on data from January 1, 2011 thru June 9, 2021.....	5-15
Table 5.2-6.	Diablo Lake WSE statistics (2011 to 2021).....	5-19
Table 5.2-7.	Gorge Lake WSE statistics (2011 to 2021).....	5-20
Table 5.2-8.	Diablo Lake WSE statistics by month of year based on data from January 1, 2011 thru June 9, 2021.....	5-22
Table 5.2-9.	Gorge Lake WSE statistics by month of year based on data from January 1, 2011 thru June 9, 2021.....	5-22
Table 5.2-10.	Diablo Lake WSE statistics by month of year based on data from January 1, 2011 thru June 9, 2021.....	5-25
Table 5.2-11.	Gorge Lake WSE statistics by month of year based on data from January 1, 2011 thru June 9, 2021.....	5-25
Table 5.3-1.	Observations of fish stranding and trapping observed during field surveys.....	5-44
Table 6.2-1.	Status of Stranding and Trapping Assessment modifications identified in the June 9, 2021 Notice.....	6-1
Table 7.0-1.	Refined data collected during field surveys under each scenario.	7-2

Table 7.0-2. Data mentioned in RSP that are not being collected, and rationale for omission.	7-3
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List of Attachments

Attachment A	Maps of Sampling Locations on Ross Lake
Attachment B	Maps of Sampling Locations on Diablo and Gorge Lakes

List of Acronyms and Abbreviations

°C	degrees Celsius
ACS.....	adaptive cluster sampling
City Light.....	Seattle City Light
CoSD.....	City of Seattle datum
DEM.....	digital elevation model
FERC.....	Federal Energy Regulatory Commission
GIS	Geographic Information System
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
ISR	Initial Study Report
km	kilometer
LiDAR.....	Light Detection and Ranging
LP	licensing participant
NAVD 88	North American Vertical Datum of 1988
NPS	National Park Service
PME	protection, mitigation, and enhancement
Project	Skagit River Hydroelectric Project
PWE	Problem Water Elevation
RSP	Revised Study Plan
SAGA.....	System for Automated GIS Analysis
SR.....	State Route
SRS	stratified random sampling
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
USR.....	Updated Study Report
WSE	water surface elevation

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1.0 INTRODUCTION

The FA-03 Reservoir Fish Stranding and Trapping Assessment (Stranding and Trapping Assessment) 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). 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 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, and Washington Department of Fish and Wildlife). The June 9, 2021 Notice included agreed to modifications to the Stranding and Trapping Assessment.

In its July 16, 2021 Study Plan Determination, FERC approved the Stranding and Trapping Assessment with modifications. Specifically, FERC recommended removing the placeholder from the study plan (as described in the June 9, 2021 Notice) requiring City Light to potentially expand the scope of the study in 2022 to include field studies in the Canadian portion of Ross Lake. This determination was based upon FERC’s conclusion that it had no authority to require City Light to implement studies in Canada. Notwithstanding, City Light is implementing the Stranding and Trapping Assessment as proposed in the RSP with the agreed modifications described in the June 9, 2021 Notice.

On March 8, 2022, City Light filed its Initial Study Report (ISR). No requests for modifications to the Stranding and Trapping Assessment were filed. FERC’s August 8, 2022 Determination on Requests for Study Modification required no modifications to the Stranding and Trapping Assessment.

This study is complete and a report of the study efforts is being filed with FERC as part of City Light’s Updated Study Report (USR).

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

2.0 STUDY GOALS AND OBJECTIVES

The goal of the Stranding and Trapping Assessment is to assess the risk of stranding and trapping native fish species within the study area under normal Project operations.² Native fish species within Project reservoirs include resident Rainbow Trout (*Oncorhynchus mykiss*), Bull Trout (*Salvelinus confluentus*), and Dolly Varden (*Salvelinus malma*).

Specific objectives outlined in the RSP include:

- Identify and map focal areas through a desktop Geographic Information System (GIS) analysis of existing elevation and topo bathymetric data where stranding and trapping risk to native fish species may occur;
- Undertake field surveys of fish stranding and trapping at select risk areas to confirm or refute the results of the desktop analysis methods; and
- As needed, update the desktop analysis based on field results.

In addition, the June 9, 2021 Notice identified four clarifications related to implementation of this Stranding and Trapping Assessment:

- City Light to hold technical meetings with the LPs to review initial information to assess adequacy of that information (related to the spatial scale of data) in informing stranding evaluation (including tree well size) and to guide representative sampling in the fourth quarter of 2021.
- Review 2021 sampling in the U.S. for risk assessment to refine and inform the expansion to Canadian drawdown zone in 2022.
- LPs requested that the study results inform the development of protection, mitigation, and enhancement (PME) measures inclusive of a reservoir drawdown rate that avoids, limits, or greatly reduces stranding of fish and juvenile amphibians and identifies reservoir elevations that prove problematic for trapping of fish and juvenile amphibians. City Light and the LPs recognize that the study report will not include proposed PME measures related to stranding. Such PME measures will be developed as part of the license application with consideration of downstream flow and other impacts.
- City Light will clarify the study to provide for opportunistic surveys if maintenance drawdowns or lowering of reservoirs beyond normal operations occurs.

Two objectives previously described in the June 9, 2021 Notice were agreed during a subsequent consultation with LPs on October 20, 2021 to be on an "if needed" basis. These objectives were confirmed for implementation in consultation with LPs on October 20, 2021:

- Finding a reservoir drawdown rate that avoids, limits, or greatly reduces stranding of fish and juvenile amphibians; and

² For purposes of this study, "normal operations" are defined as typical operations to support flood control, fish protection, recreation, and power generation and do not include drawdowns for maintenance or infrastructure testing. Normal operations are further defined in Section 3.0 of this report.

- Identifying reservoir elevations that prove problematic for trapping of fish and juvenile amphibians.

3.0 STUDY AREA

The study area includes Ross, Diablo, and Gorge lakes, within the U.S. and Canada, and specifically targets the varial zone at which stranding and trapping risks could occur under normal Project operations (Figure 3.0-1). The GIS analysis area extends into the portion of Ross Lake in Canada approximately 1.4 kilometers (km) north of the Canada-U.S. border (outside of the Project Boundary). The initial field survey area includes the Project reservoirs within the U.S. only.

Under the current Project license, Ross Lake normal maximum water surface elevation (WSE) and normal operating minimum WSE (authorized by current Project license) are 1,608.76 feet North American Vertical Datum of 1988 (NAVD 88; 1,602.5 feet City of Seattle datum [CoSD])³ and 1,480.76 feet NAVD 88 (1,474.5 feet CoSD), respectively. Water surface elevations are typically maintained between a normal maximum of 1,608.76 feet NAVD 88 (1,602.5 feet CoSD) during summer and 1,541.26 feet NAVD 88 (1,535 feet CoSD) during fall and winter (a difference of 67 feet). The varial zone below the normal maximum WSE to the seasonal drawdown level comprises the study area of Ross Lake.

Diablo Lake may fluctuate 4 to 5 feet daily for a typical operating range between about 1,206 and 1,211 feet NAVD 88 (between about 1,199.64 and 1,204.64 feet CoSD). Occasionally, Diablo Lake may be operated as low as elevation 1,203 or 1,204 feet NAVD 88 (1,196.64 and 1,197.64 feet CoSD) under normal operations. Drawdowns of 10 to 12 feet to about elevation 1,200 feet NAVD 88 (1,193.64 feet CoSD) also occur as needed for construction projects or maintenance. The varial zone exposed during typical (normal) fluctuations constitutes the primary study area of Diablo Lake.

Gorge Lake typically fluctuates 3 to 5 feet daily, for a typical operating range between about 876 and 881 feet NAVD 88 (between about 869.49 and 874.49 feet CoSD). Under normal operations the lake may be operated as low as 870 feet NAVD 88 (863.49 feet CoSD) on occasion. Drawdowns to approximately 831.51 feet NAVD 88 (825 feet CoSD) are occasionally needed for spill gate maintenance or inspection.⁴ The varial zone exposed during typical (normal) fluctuations constitutes the primary study area of Gorge Lake.

For the remainder of this document, reported WSE have been rounded to the nearest tenth of a foot.

³ As described in Section 2.3.1 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.

⁴ The normal operating minimum WSE for Gorge Lake is 873.51 ft NAVD 88 (867 ft CoSD), which was recently identified by City Light fisheries biologists to reduce fish stranding risk.

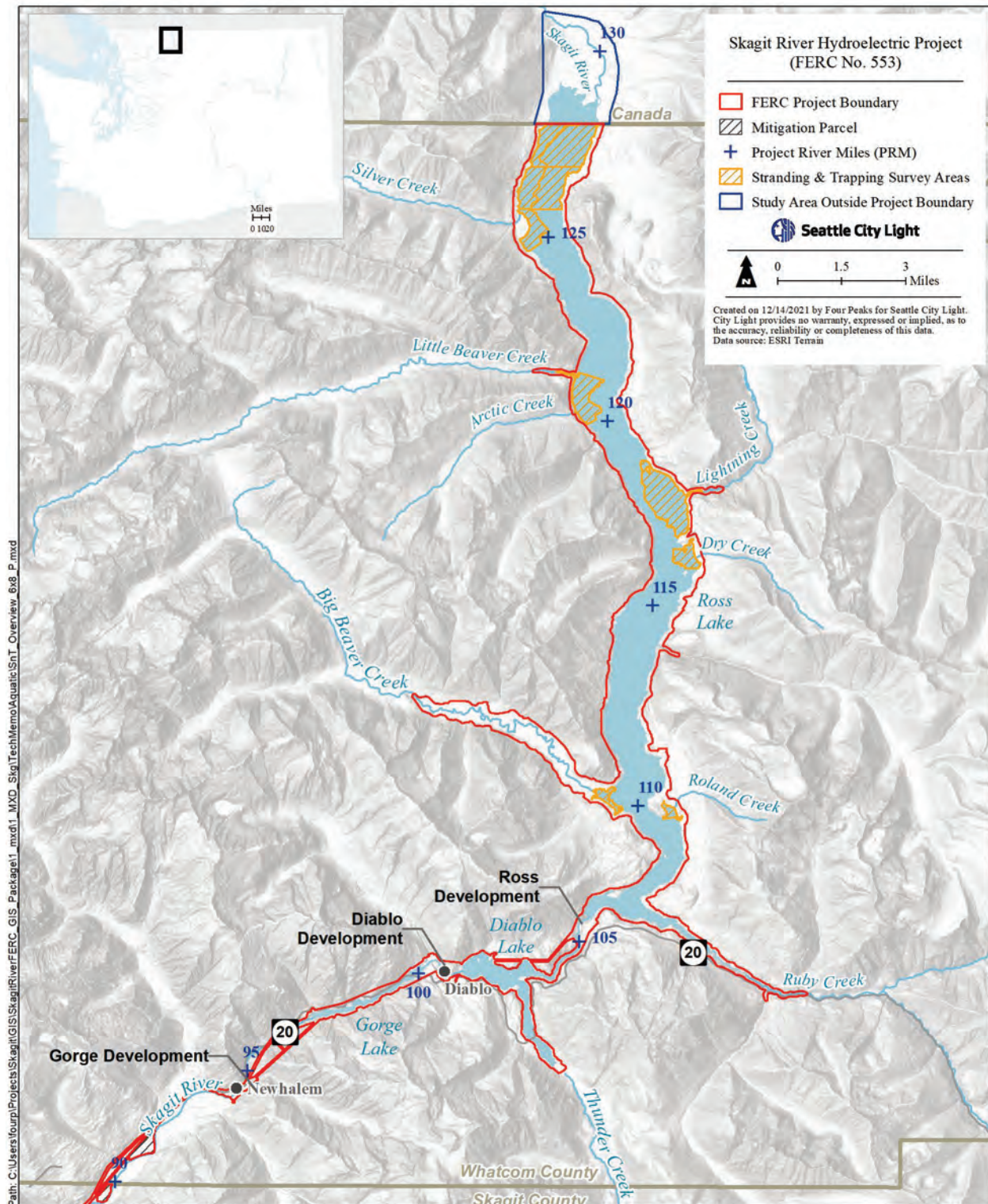


Figure 3.0-1. Overview of study area.

4.0 METHODS

The Stranding and Trapping Assessment includes four distinct tasks: (1) field reconnaissance; (2) a desktop analysis of the study area to identify potential areas of fish stranding and trapping risk; (3) field surveys at selected areas to test the results of the desktop analysis; and (4) an update to the desktop analysis, if necessary.

4.1 Reconnaissance Surveys

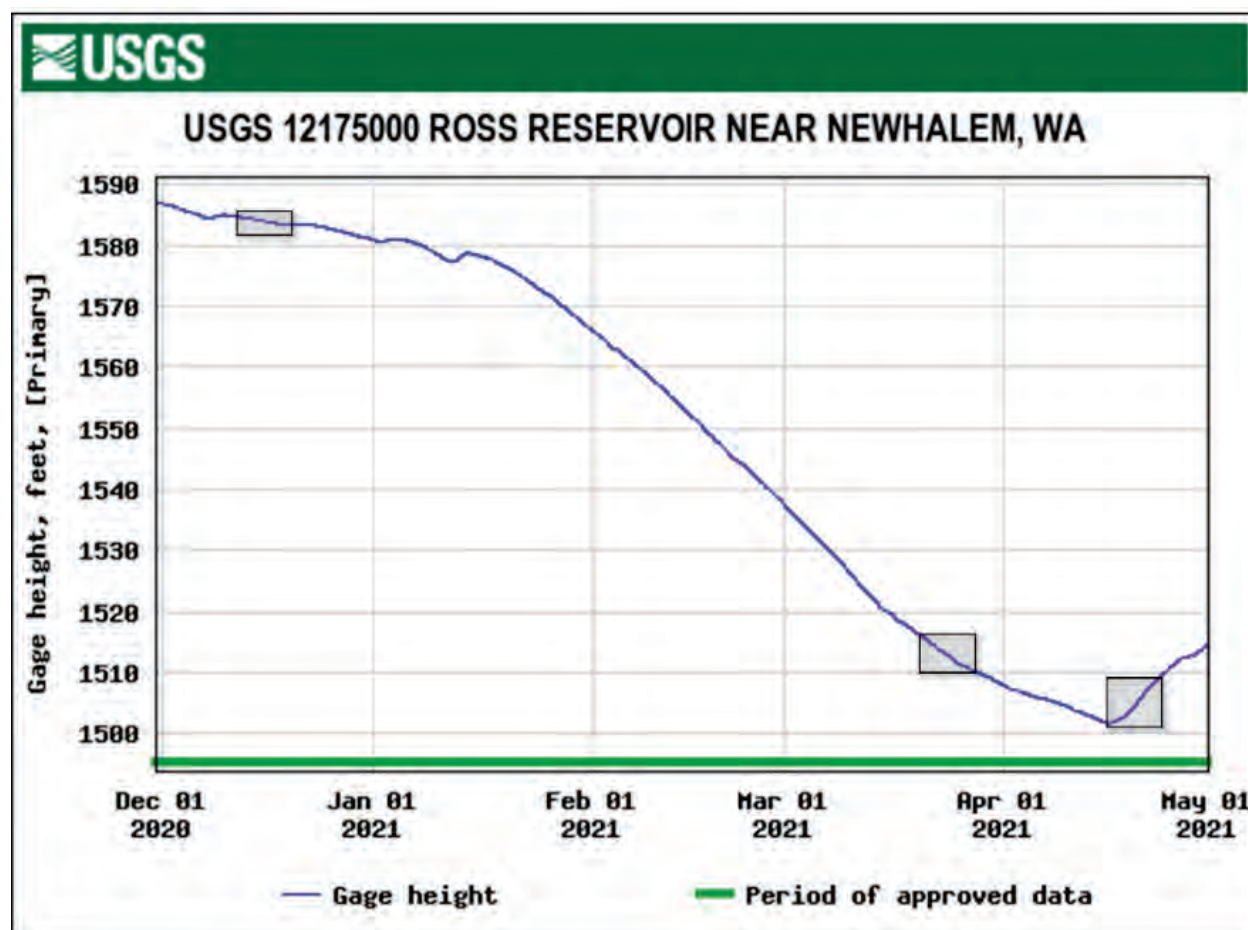
A total of three reconnaissance field surveys were conducted on Ross Lake during the 2020 and 2021 drawdown cycle—in December 2020, March 2021, and April 2021—to capture various points in the drawdown cycle. Additionally, one opportunistic reconnaissance survey was conducted on Diablo Lake in September 2020 to capitalize on an unplanned drawdown beyond the normal operations of that reservoir.

These reconnaissance efforts served four main purposes associated with optimizing the formal field program planned for 2021-2022 (2021-2022 Ross Lake drawdown cycle, the 2022 Gorge and Diablo lakes quarterly sampling, and opportunistic sampling of reservoir drawdown events below the range of normal operations, as defined by the study):

- (1) Identify areas around Project reservoirs with high concentrations of potential stranding or entrapment habitat (e.g., tree wells, low-slope areas), including refining the boundaries that define these areas;
- (2) Refine the methodology for spatial sampling and field surveying;
- (3) Identify shoreline access issues and other logistical challenges for each lake; and
- (4) Optimize the sequence of sampling study zones, both throughout the season and within each survey.

4.1.1 Ross Lake Reconnaissance

Reconnaissance field surveys on Ross Lake were conducted between December 2020 and April 2021, a period spanning most of the 2020-2021 reservoir drawdown and the beginning of reservoir refill. Consequently, WSE in Ross Lake varied by more than 80 feet over this period (Figure 4.1-1).



Note: Water surface elevation presented in feet above CoSD. Shaded rectangular boxes indicate approximate periods of reconnaissance surveys. Figure from U.S. Geological Survey ([USGS] 2022a).

Figure 4.1-1. Ross Reservoir (i.e., Ross Lake) WSE from December 2020 through April 2021.

Ross Lake reconnaissance surveys focused on areas around Ross Lake that were identified as having a known or hypothesized high potential risk of stranding and trapping, based on input from LPs, preliminary desktop analyses, and prior experience of City Light staff, including iterative development of these areas based on observations during the reconnaissance efforts. The areas identified by these processes included locations where stranding and trapping had been observed previously by LPs, locations where existing information on topographic slope and bathymetry in exposed areas suggested potential for stranding and trapping, and locations that were considered likely stranding and trapping risk areas based on best professional judgment and past findings in other systems (e.g., areas close to a tributary outflow). Both the identification of these meso-scale focus areas and the precise delineation of their respective boundaries were iteratively refined through the reconnaissance period; for example, to account for feedback provided during consultation with LPs on October 20, 2021, and from review of empirical data collected during the reconnaissance surveys on Ross Lake.

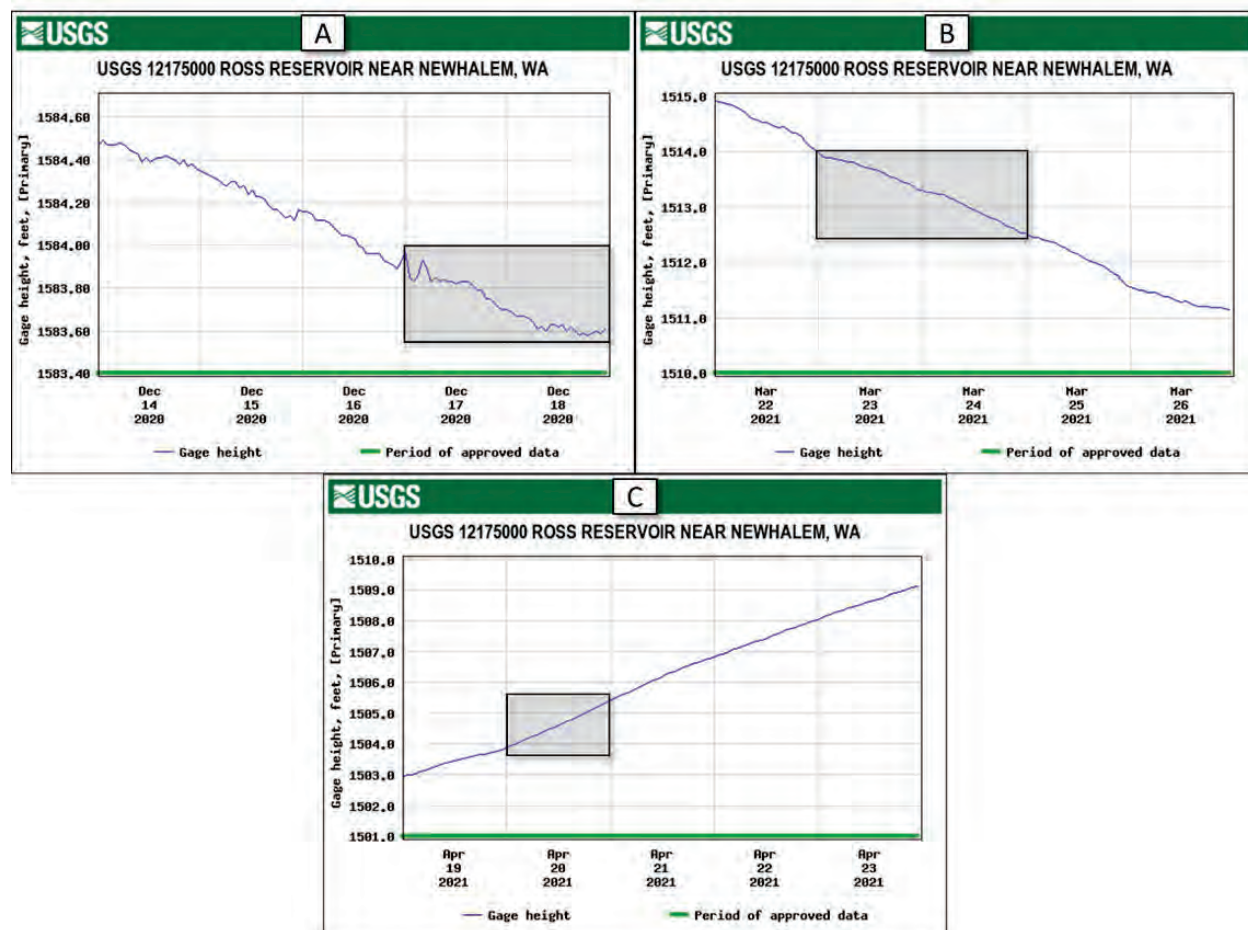
These reconnaissance focus areas represent early risk screening “strata.” Within these strata, which represent a substantial area of survey within Ross Lake in particular, the adaptive cluster sampling (ACS) approach (defined further in Section 4.3 herein) was evaluated for application later in 2021

and in 2022 after the digital elevation model (DEM) results described in Section 4.2 were complete. The results of these surveys also informed the desktop analysis described in Section 4.2.

The first reconnaissance survey on Ross Lake was conducted on December 17-18, 2020, when Ross Lake WSE measured at U.S. Geological Survey (USGS) gage 12175000 was approximately 1,590.3 feet NAVD 88 (1,584 feet CoSD; Figure 4.1-2A). On December 17, 2020, crews surveyed the northern part of the eastern shore of the lake, north of the Hozomeen Fish Camp. On December 18, 2020, crews surveyed the northern part of the western shore of the lake, beginning opposite Hozomeen Fish Camp, then surveyed around the mouth of Big Beaver Creek and dispersed shoreline areas along the southern end of the lake. During this visit, crews evaluated the logistics of sampling 10 percent of the dewatered varial zone and tested field-based delineation of 25-meter quadrats. Within each quadrat, crews visually searched for evidence of stranded or trapped fish, including dead fish, fish remains, and topographic features that were holding water.

A second reconnaissance survey on Ross Lake was conducted on March 24, 2021, when Ross Lake WSE measured at the USGS gage was approximately 1,519.3 to 1,520.3 feet NAVD 88 (1,513 to 1,514 feet CoSD, Figure 4.1-2B). The varial zone was surveyed around the mouths of Roland Creek, Big Beaver Creek, and Lightning Creek, around Lost Lake, and within the Ruby Arm where Ruby Creek flows into Ross Lake.

A third and final reconnaissance survey on Ross Lake was conducted on April 20, 2021, when Ross Lake WSE measured at the USGS gage was approximately 1,511.3 feet NAVD 88 (1,505 feet CoSD, Figure 4.1-2C). On this date, the crew attempted to survey the north end of the lake, but water level was too low, and conditions were too shallow to safely proceed past the approximate location of Jack Point in the boat. The crew attempted passage using a smaller motorized raft, but the current was too strong to pass, and no further attempts were made. The crew then resampled areas around the mouth of Lightning Creek and around Lost Lake using randomly selected starting locations as part of the stratified random sampling (SRS) plan. Next, the crew surveyed the varial zone along both the south and north sides of the mouths of Little Beaver Creek and Arctic Creek.



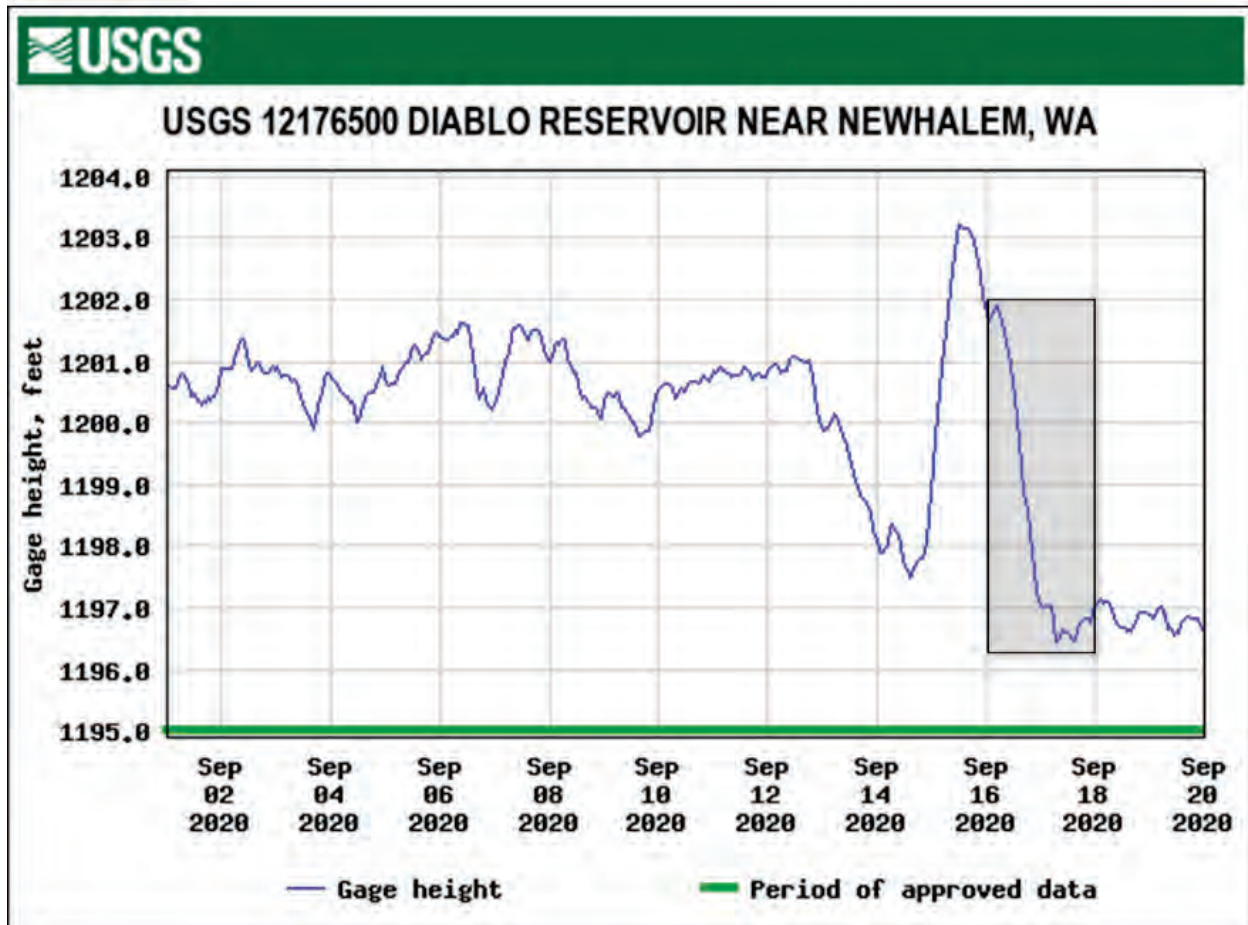
Note: Water surface elevation presented in feet above CoSD. Shaded rectangular boxes indicate approximate periods of reconnaissance surveys. Figure from USGS (2022a).

Figure 4.1-2. Ross Reservoir (i.e., Ross Lake) WSE at the time of each of the reconnaissance surveys: (A) December 17-18, 2020, (B) March 23-24, 2021, and (C) April 20-21, 2021.

4.1.2 Opportunistic Diablo Lake Reconnaissance

On September 16-17, 2020, Diablo Lake was opportunistically surveyed for stranded or trapped fish during an unplanned drawdown for previously unscheduled maintenance. During this event, the reservoir was drawn down nearly 6 feet (7 feet from normal maximum WSE), to a WSE of approximately 1,202.4 to 1,207.4 feet NAVD 88 (1,196 to 1,201 feet CoSD) as measured at USGS gage 12176500 near Newhalem, Washington (Figure 4.1-3).

Sampling around Diablo Lake began between 0730 and 0900 on each day. Sampled locations included areas upstream (south) of the State Route (SR) 20 bridge, including sites in Thunder Arm.



Note: Water surface elevation presented in feet above CoSD. Shaded rectangular boxes indicate approximate periods of reconnaissance surveys. Figure from USGS (2022b).

Figure 4.1-3. Diablo Reservoir (i.e., Diablo Lake) WSE during mid-September 2020.

4.2 Desktop Analysis

The desktop analyses included three components, as described in Section 2.6.2 of the RSP: (1) assembly and analysis of DEMs of reservoir shoreline and bed topography to inventory potential stranding and trapping areas; (2) an analysis of reservoir WSE data to document the frequency and period of time over which trapping pools are formed and areas of low slope terrain are exposed in drawdown zones; and (3) an analysis of native species life stage and periodicity information to identify when life stages susceptible to stranding and trapping risk under normal operations may be present in the study area.

4.2.1 Analysis of DEMs for Potential Stranding and Trapping Risk Areas

4.2.1.1 Data Sources and Preparation

Digital elevation models were analyzed to identify areas presenting potential stranding and trapping risk. For Ross Lake, the DEM was developed by the study team from the 2018 terrestrial Light Detection and Ranging (LiDAR) flight (Quantum Spatial 2018a). This 2018 flight was conducted when the WSE measured at Ross Dam was 1,494.3 feet NAVD 88 (1,488 feet CoSD),

which is approximately 6.5 feet above the minimum recorded WSE during the study period. As a result, the lowest elevation stratum of Ross Lake shoreline was not represented within these data.

The Diablo Lake DEM was compiled by the study team from multiple sources. These included a Thunder Arm DEM derived from shallow-water-penetrating green LiDAR collected by Quantum Spatial (2018b), multibeam SONAR bathymetry of the full lake collected by the study team in 2022, and terrestrial LiDAR collected in 2016 by Quantum Spatial on behalf of USGS to supplement coverage of the varial zone outside of Thunder Arm. Based on best professional judgment of the data quality and spatial coverage of these three sources, these data were used in the following ways for subsequent analyses:

- Low slope analysis: used topobathy clipped to extent of original green LiDAR dataset.
- Sinks analysis: used original green LiDAR dataset.

In addition, analyses within Diablo Lake focused only on the Thunder Arm region. This was because the green LiDAR data only covered Thunder Arm, and in the absence of this green LiDAR, the resulting gap between the bathymetry and terrestrial LiDAR encompassed most of the varial zone throughout the remainder of the reservoir.

The Gorge Lake DEM was compiled by Northwest Hydraulic Consultants from green LiDAR (Quantum Spatial 2018b), multibeam SONAR bathymetry (collected by NW Hydro on behalf of HDR), and terrestrial LiDAR (collected in 2016 by Quantum Spatial on behalf of USGS).

4.2.1.2 Geospatial Analyses

To identify potential stranding risk areas, the slope was calculated for each grid cell (1-meter resolution or 1 square meter per grid cell for the Diablo topobathymetry DEM, 3-foot resolution or 9 square feet for all other DEMs). Cells with a slope of less than or equal to 4 percent were categorized as low-slope areas based on benchmark slopes identified by Bell et al. (2008) as associated with salmonid stranding potential in reservoir environments. To eliminate overly granular slope classification, areas of potential stranding risk were identified as the union of two or more adjacent or diagonal low-slope cells (18 square feet minimum), consistent with the approach described in the RSP (City Light 2021).

Trapping hazards were identified as sinks greater than 108 square feet in area and deeper than 12 inches compared to the surrounding surface. Sinks were identified by using the sink-filling algorithm (Wang and Liu 2006) within the Terrain Analysis toolbox in the System for Automated GIS Analysis (SAGA) v7.9.1 (Conrad et al. 2015). The elevation difference between the filled and unfilled DEMs was calculated in ArcGIS Pro, retaining only those sinks deeper than 12 inches and larger than 108 square feet. The minimum (rim) elevation of the sink was assigned to the entire sink to categorize the trapping risk area exposed when the lake WSE draws down past the elevation of the sink rim. While the area threshold of 108 square feet may omit smaller sinks, reconnaissance efforts during study planning indicate the following, in support of this minimum size criterion:

- (1) Sinks tend to cluster. The likelihood of detecting at least one sink meeting the minimum size threshold within a given area is high.

- (2) Sinks tend to co-occur with low slope areas. The GIS analyses of slope, to identify areas that present a stranding risk, included a smaller areal size threshold of more than one contiguous 1-foot cell meeting the slope criteria. Small patches of low slope terrain were thus identified within the analysis, and these features presumably encompass many of the very small trapping pools (sink features).

Based on reconnaissance field survey results, low slope and sink areas around Ross Lake that were contiguous with the mainstem Skagit River thalweg were manually removed from the analysis, as they are never dewatered, even at full drawdown. This step was necessary because the terrestrial LiDAR did not distinguish between exposed land and water surface. This lack of distinction meant that areas with flowing water at the time of imagery collection (i.e., the mainstem Skagit River thalweg and its primary side channels) could have been identified as low slope or sink areas or have impacted the sink areas identified by the sink filling algorithm.

In Diablo and Gorge lakes, such false flat or low slope areas were not an issue, because these DEMs were derived from a combination of terrestrial LiDAR, green LiDAR, and bathymetry. However, the sink analysis does not distinguish between sinks that were dewatered during drawdown events and mid-channel pools that are continuously inundated at all reservoir levels by flows from either the Skagit River or, in Diablo Lake, Thunder Creek. As a result, sinks that appeared to be pools in the main thalweg of these two streams were manually removed from the analysis.

As described in Section 4.1, this desktop analysis was conducted iteratively with the Ross Lake reconnaissance surveys to ensure that areas identified in the field as having a high potential risk of stranding and trapping were accurately identified by the GIS analyses. For example, areas of moderate slope (4-6 percent) were also identified by Bell et al. (2008) to have potential stranding risk, albeit to a lower degree. However, based on field observations in Ross and Diablo lakes, these areas were too steep to strand fish and were thus excluded from the stranding desktop analysis.

4.2.2 Analysis of Reservoir Drawdown

The purpose of the WSE analysis was to characterize the time series of WSE in the reservoirs at daily, monthly, annual, and decadal time scales, for planning field surveys and for characterizing the risk associated with the topographic features identified by the geospatial analyses at different WSE. To meet this goal, analyses included identification of consistent patterns in reservoir drawdown that occur at certain periods of the year. Results from these analyses were then used to identify the timing, frequency, and duration of risk that emerged when potential stranding and trapping features around each reservoir were dewatered.

Records of hourly and daily gage height were obtained for the three reservoirs from the USGS website (USGS 2022a, 2022b, 2022c) for the period of January 1, 2011, through June 9, 2021, as specified in the RSP (City Light 2021). As described in Section 3.0, the gage height was converted from CoSD to NAVD 88 by adding the following offsets to the gage readings:

- Ross Lake: 6.26 feet.
- Diablo Lake: 6.36 feet.
- Gorge Lake: 6.51 feet.

All data were collated and then screened for data gaps and outliers. The longest notable data gaps were:

- Ross Lake: Two days (two occurrences) and one day (one occurrence).
- Diablo Lake: Three days (one occurrence) and one day (two occurrences).
- Gorge Lake: Four days (one occurrence), two days (two occurrences), and one day (one occurrence).

For each reservoir, there were no observations of WSE above or below the licensed operating level.

Data records were then binned into 1-foot bin sizes between the minimum and maximum WSE recorded over the period considered, and the frequency distribution and percentiles were determined to calculate frequency of occurrence and percent exceedance curves (Helsel et al. 2020). Bulk statistics (minimum, maximum, mean, median, range, variance) were also calculated for the dataset. Data operations (calculation of frequency of occurrence, percent exceedance, and bulk statistics) were completed for the full dataset (2011 to 2021) and by month of year and week of year.

Diablo and Gorge lakes water level records were analyzed to identify drawdown events that occur primarily on an hourly to daily timescale but can also last longer (up to approximately one month). Drawdown events were also characterized for Ross Lake, where fluctuations are typically associated with an annual drawdown cycle. The following criteria were used to characterize events at all three reservoirs:

- Rim elevation (threshold elevation in 1-foot increments);
- Duration (minimum of one hour); and
- Minimum drawdown or decrease in WSE from the rim elevation (greater than 0).

An event was identified each time the WSE dropped below the rim elevation and then returned to the rim elevation after meeting the minimum threshold duration and drawdown criteria. Following this methodology, drawdown events can be counted multiple times depending on the starting rim elevation. Statistics were calculated for the drawdown events at each rim elevation, and included:

- Start and end time of the event;
- Duration of the event;
- Minimum WSE;
- Drawdown rate; and
- Monthly and weekly statistics (count and percent occurrence).

4.2.3 Integration of Reservoir Drawdown and GIS Analyses

In order to assess the magnitude of stranding and trapping risk presented by potential risk areas identified in Section 4.2.1, the frequency, duration, and timing of drawdown events at 1-foot intervals within normal operating WSE were assessed in the context of the area of potential stranding and trapping risk at those elevations. The number of monthly drawdown events for the

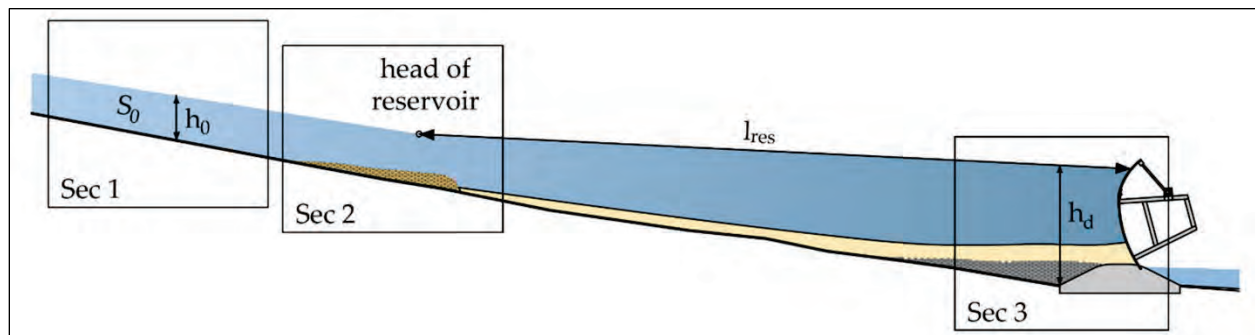
period of record was compared across elevation bands and was multiplied by the area of stranding and trapping risk areas to create an index of stranding and trapping risk broken out by month and elevation band. In addition, the duration of each drawdown event was compared across elevation bands.

4.2.4 Native Species Life Stage and Periodicity Analysis

Periodicity for native fishes was developed by gathering and reviewing literature and reports specific to the Project area and similar regional environments. Reports were gathered by searching for relevant keywords and phrases. Papers and reports were reviewed for information on the seasonal habits of these fish in the Project's streams and reservoirs and within similar environments. Data were then compiled into a month-by-month table showing fish use throughout the year, by species, life stage (spawning, fry, juvenile, and adult), and geographic area (shallow lake, deep water lake, streams, and stream inlets).

4.2.5 Ross Lake Longitudinal Water Surface Elevation Profile

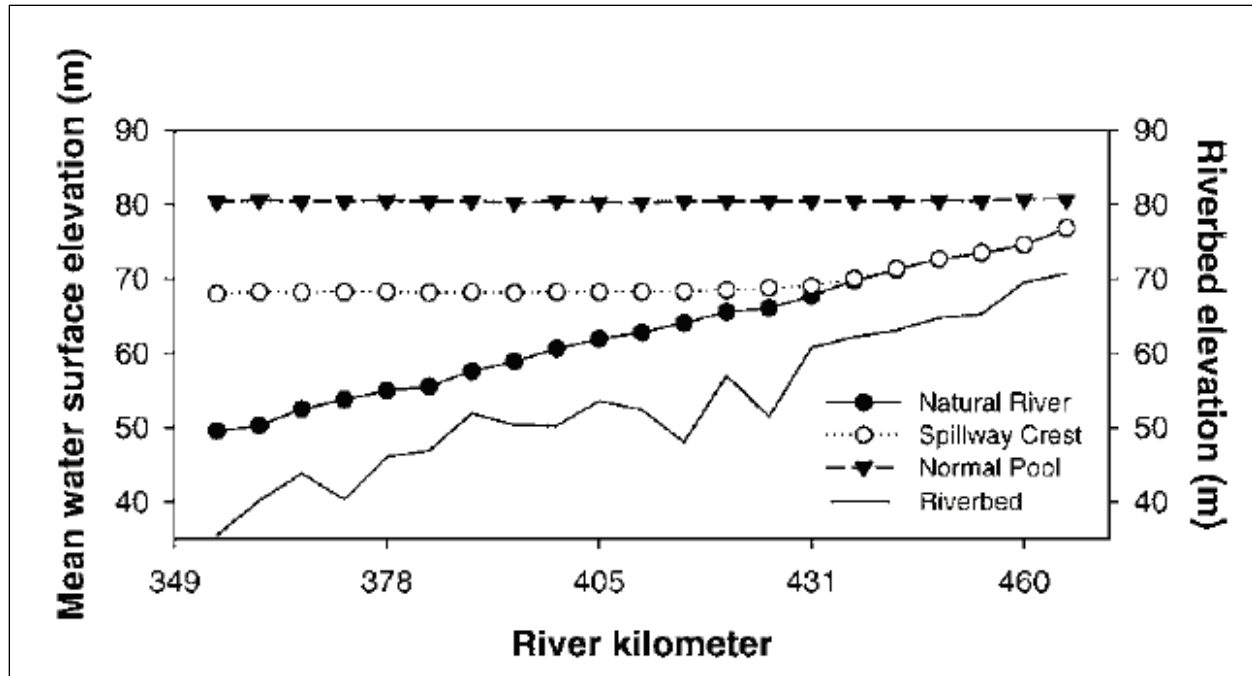
Information describing the shape of the water surface along the length of Ross Lake, and how this shape changes through drawdown operations, has implications for the planning of field surveys and the interpretation of GIS analyses, but was unknown at the time of study planning. Impounded reservoirs tend to exhibit a longitudinal profile, with variable slope that depends on position within the reservoir and reservoir geometry (Sindelar et al. 2020; Figure 4.2-1).



Note: Figure and caption after Sindelar et al. (2020). S_0 indicates bed slope, h_0 indicates water depth in the free-flowing section above the reservoir head, h_d indicates water depth at the dam, and l_{res} indicates reservoir length.

Figure 4.2-1. Scheme of a run of river hydropower plant showing longitudinal section from the dam to the head of the reservoir (bottom).

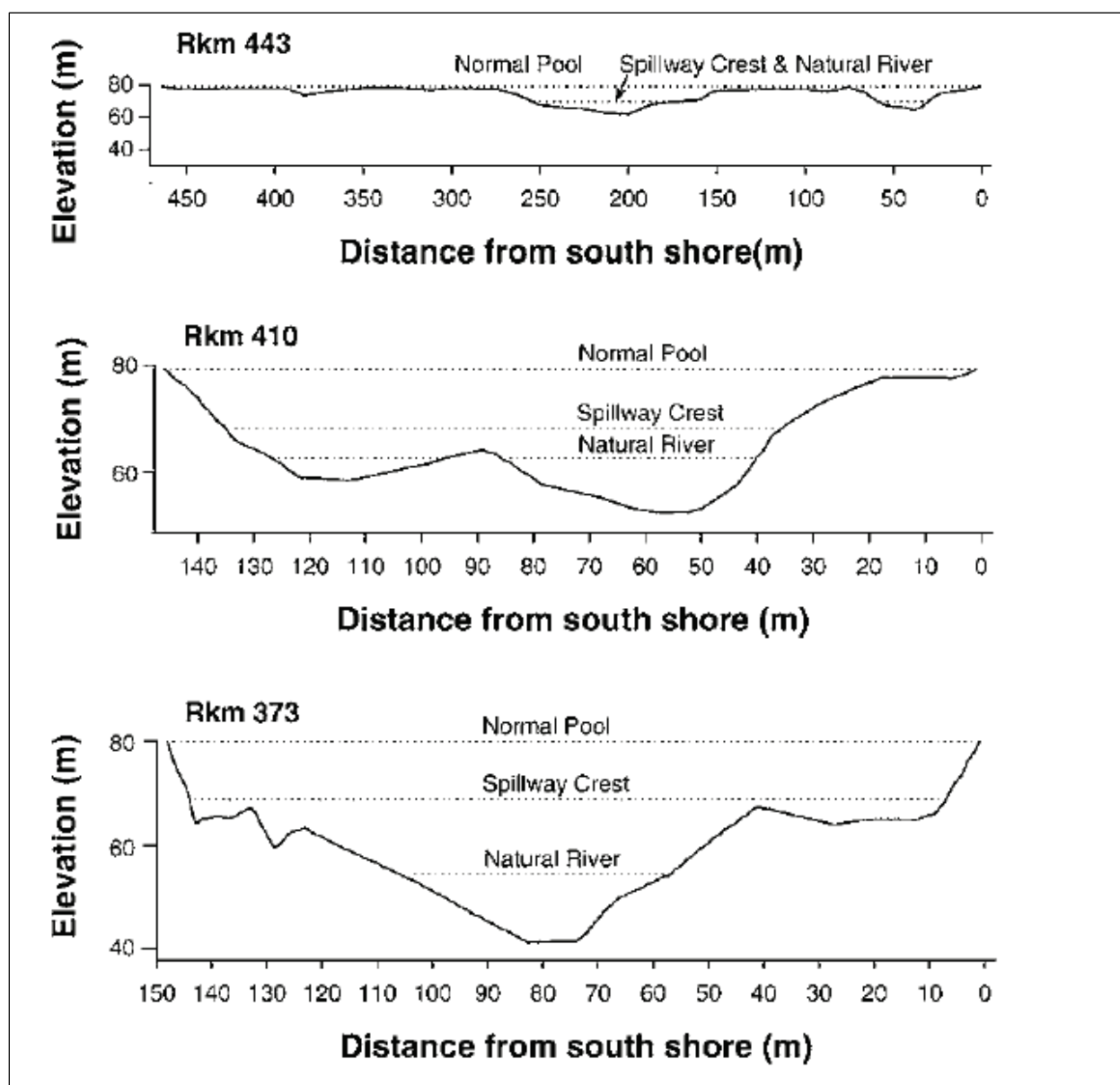
This profile also changes during reservoir drawdown (Tiffan et al. 2006; Figure 4.2-2). WSE is generally flat within the reservoir when it is near maximum WSE. As a reservoir is drawn down below the elevation of its spillway crest, this longitudinal profile develops a slope (Tiffan et al. 2006). Under the extreme condition (no dam), the slope of the water surface within the reservoir would match that of the historical river, as exemplified for the John Day reservoir on the Columbia River in Figure 4.2-2.



Note: Figure and caption after Tiffan et al. (2006). Within this figure, the dam is located to the left of (outside) the axes shown, near River km 347. “Normal Pool” line in figure is analogous to a situation where WSE is near maximum, “Spillway Crest” is analogous to WSE near the middle of the operational range, and “Natural River” is analogous to WSE near minimum.

Figure 4.2-2. Longitudinal profile of model-predicted water surface elevations within John Day Reservoir (Columbia River) under differing operational scenarios.

This phenomenon has two implications for the Stranding and Trapping Assessment. First, at some point in drawdown (presumably between maximum WSE and when water drops below the spillway crest around 1,588.3 feet NAVD 88 [1,582 feet CoSD]), WSE begins to vary across Ross Lake. Below this threshold, WSE measurements at the dam do not accurately represent WSE at all points around Ross Lake. Instead, the water levels at points near the head of the reservoir are higher in elevation compared to those at the dam. For example, when WSE at Ross Dam is 1,556.3 feet NAVD 88 (1,550 feet CoSD), WSE near Hozomeen is higher. Second, as drawdown proceeds toward seasonal minimum, the magnitude of WSE change at the dam is dampened as it translates throughout the reservoir. For example, when WSE at Ross Dam is 1,536.3 feet NAVD 88 (1,530 feet CoSD) and then drops by feet, the change in WSE near Hozomeen is less than feet. Thus, apparent rapid drops at the dam may not actually manifest as substantial changes in WSE at locations further upstream in the reservoir (Figure 4.2-3).



Note: Figure and caption after Tiffan et al. (2006). The dam affecting WSE shown in this figure is located near River km 347. Thus, the bottom panel reflects conditions closer to the dam face, and the top panel reflects conditions near the reservoir head. “Normal Pool” line in figure is analogous to a situation where WSE is near maximum, “Spillway Crest” is analogous to WSE near the middle of the operational range, and “Natural River” is analogous to WSE near minimum. Note that different operational conditions result in larger changes in WSE near the dam than occur further upstream.

Figure 4.2-3. Cross-sectional profiles at locations within John Day Reservoir (Columbia River), showing the range of water surface elevation under three drawdown scenarios.

To address this data gap, Global Positioning System (GPS) locations at the water’s edge were collected opportunistically using a handheld GPS receiver with a Global Navigation Satellite System (GNSS) antenna during two of the Stranding and Trapping Assessment field surveys (October 2021 and April 2022) and during a scouting survey for the FA-01a Water Quality Monitoring Study (May 2022; City Light 2023). Although field measurements using handheld

GPS receivers can deliver relatively precise (~1 meter) positioning of latitude and longitude, they tend to exhibit poorer elevation precision. As such, WSE for these points were estimated by mapping them onto the existing Ross Lake DEM and then assigning each point its respective DEM-derived elevation. These elevations were then plotted along with an overview map of Ross Lake to visualize the location and elevation of each measurement, and the reference WSE elevation measured at Ross Dam (Section 5.4).

4.3 Sampling Design and Field Surveys

All surveys were conducted within the normal operating range for each reservoir (see Section 3.0 for a definition of these ranges). Crews were prepared to conduct opportunistic surveys in Diablo and Gorge lakes during maintenance drawdowns or lowering of reservoirs beyond normal operations, but these drawdowns never occurred during the study period.

4.3.1 Ross Lake Sampling Design

As summarized in Section 4.1.1 herein, eight sampling areas within Ross Lake were identified for field survey in the 2021/22 field season: Mile 1,⁵ Mile 2, Silver Creek,⁶ Arctic Creek/Little Beaver Creek, Lost Lake/Lightning Creek, Dry Creek, Big Beaver Creek, and Roland Creek (Figure 3.0-1). These areas were iteratively defined, based on field reconnaissance results (described in Section 5.1 herein), preliminary analyses of reservoir elevation data, and input from LPs. Because these sampling areas are substantial in size, field surveys subsampled each, using a multi-step process to randomly sample strata within each (described in more detail in Section 5.1 herein). Including the delineation of the sampling areas themselves, this process involved five broad steps, each comprising multiple components (Figure 4.3-1). The first three steps were completed once, and results were retained for the remainder of the study. The last two steps were completed immediately before each field survey.

⁵ The “Mile 1” and “Mile 2” sampling areas refer to the varial zone shoreline areas of Ross Lake that are 1 mile and 2 miles south of the U.S.-Canada border, respectively.

⁶ Sampling areas named for creeks refer to the mouth of these creeks, where they flow into Ross Lake.

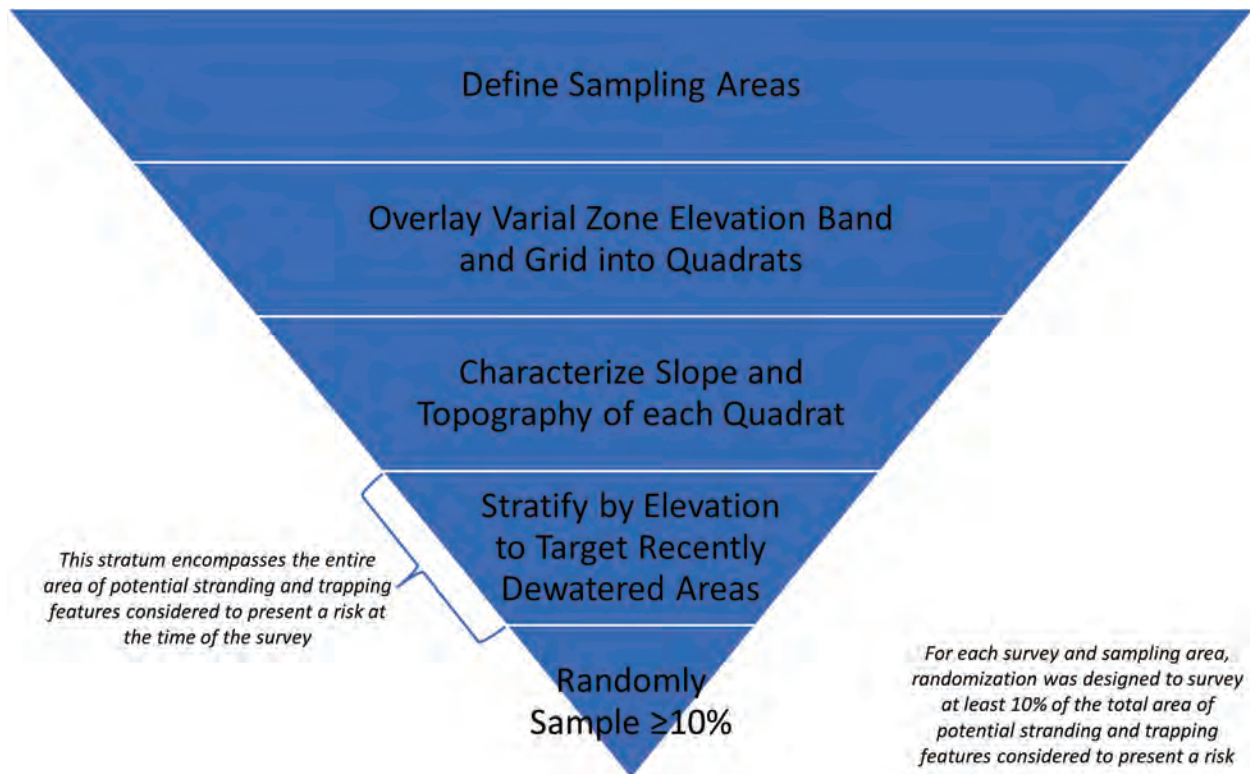


Figure 4.3-1. Process diagram for identification of stratified randomized sampling starting locations.

4.3.1.1 Stratified Adaptive Cluster Sampling Process

First, sampling areas around Ross Lake were identified based on whether they met any of the following three criteria:

- (1) Site of previous observation of stranding or trapping;
- (2) Site identified as high-risk during reconnaissance, based on observation of high concentration of tree wells or other depressional areas, or of large areas of low slope shoreline; and
- (3) Site identified during preliminary GIS analyses as potentially containing large concentrations of low slope or depressional areas.

Second, the varial zone was defined and a grid of quadrats was developed to uniquely identify locations around Ross Lake. The lower bound of the varial zone was placed at 1,494.6 feet NAVD 88 (1,488.3 CoSD), which was the WSE at the time of the 2018 LiDAR flight. The upper bound was placed at 1,608.8 feet NAVD 88 (1,602.5 CoSD), which is the maximum licensed elevation. A map of the Ross Lake varial zone was then overlaid with a grid of 25 meter-square (625 square meters) cells (quadrats). Each quadrat was then assigned a unique alphanumeric identifier (Figure 4.3-2).

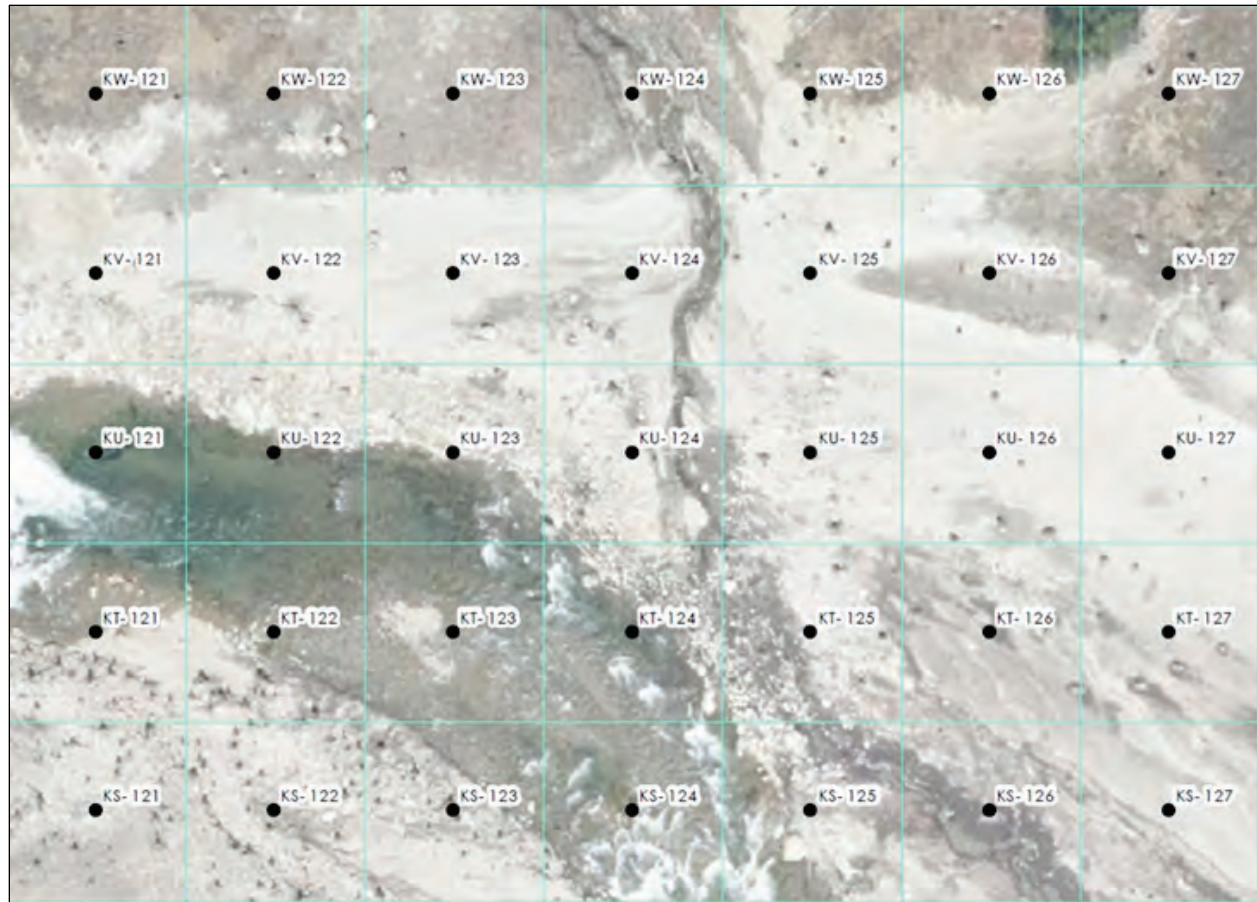


Figure 4.3-2. Area around mouth of Big Beaver Creek, showing overlaid 25-meter quadrats that are each assigned an alphanumeric identifier.

Third, low slope areas and sinks identified during the GIS analyses were added to the map (Figure 4.3-3), and each quadrat was characterized based on whether it contained a low slope feature or a sink. Using this method, each quadrat was assigned to one of four categories: (1) Low Slope; (2) Sink; (3) Both; or (4) None. The quadrats within each sampling area were subsequently stratified using these categories, as described in step four, below.

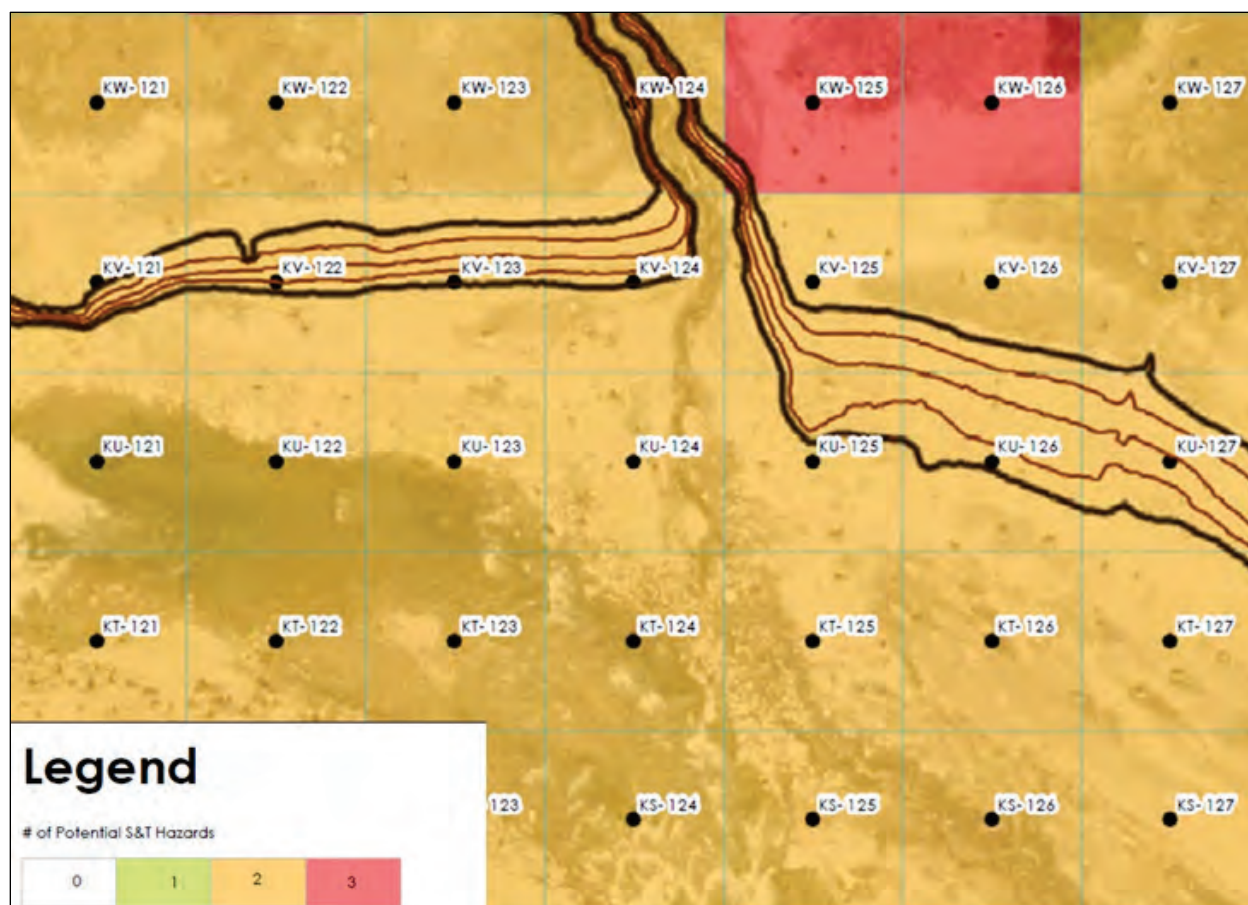


Figure 4.3-3. Area around mouth of Big Beaver Creek, showing overlaid quadrats, color coded by potential stranding and trapping group as determined from GIS-analyses. Contour lines indicate projected WSE for a potential field survey. Cells are colored based on the count of different types of features they contain.

Fourth, two to four days before a field survey, predicted Ross Lake WSE were calculated and the varial zone quadrats within each sampling area were stratified by elevation to focus on the anticipated band of recently dewatered varial zone at the time of the survey. This was done by checking the USGS Ross Lake gage (12175000), plotting the previous two weeks of WSE, and estimating daily rate of WSE change during this period (Figure 4.3-4). In addition, information about planned operational events (such as spill) was obtained from City Light and used to inform and potentially update this prediction of approximate WSE during the upcoming survey period. The predicted range of WSE was then buffered by 4 feet (i.e., 2 feet above and below the predicted WSE), to account for uncertainty. This 4-foot range of WSE was then used to stratify the quadrats within each sampling area by querying the list of all available quadrats within the varial zone, and then retaining only those quadrats that intersected with contours corresponding to the minimum and maximum elevation within the predicted WSE range (Figure 4.3-5). This final step ensured the inclusion of any grid cell with even a small portion of its total area within the stratum.

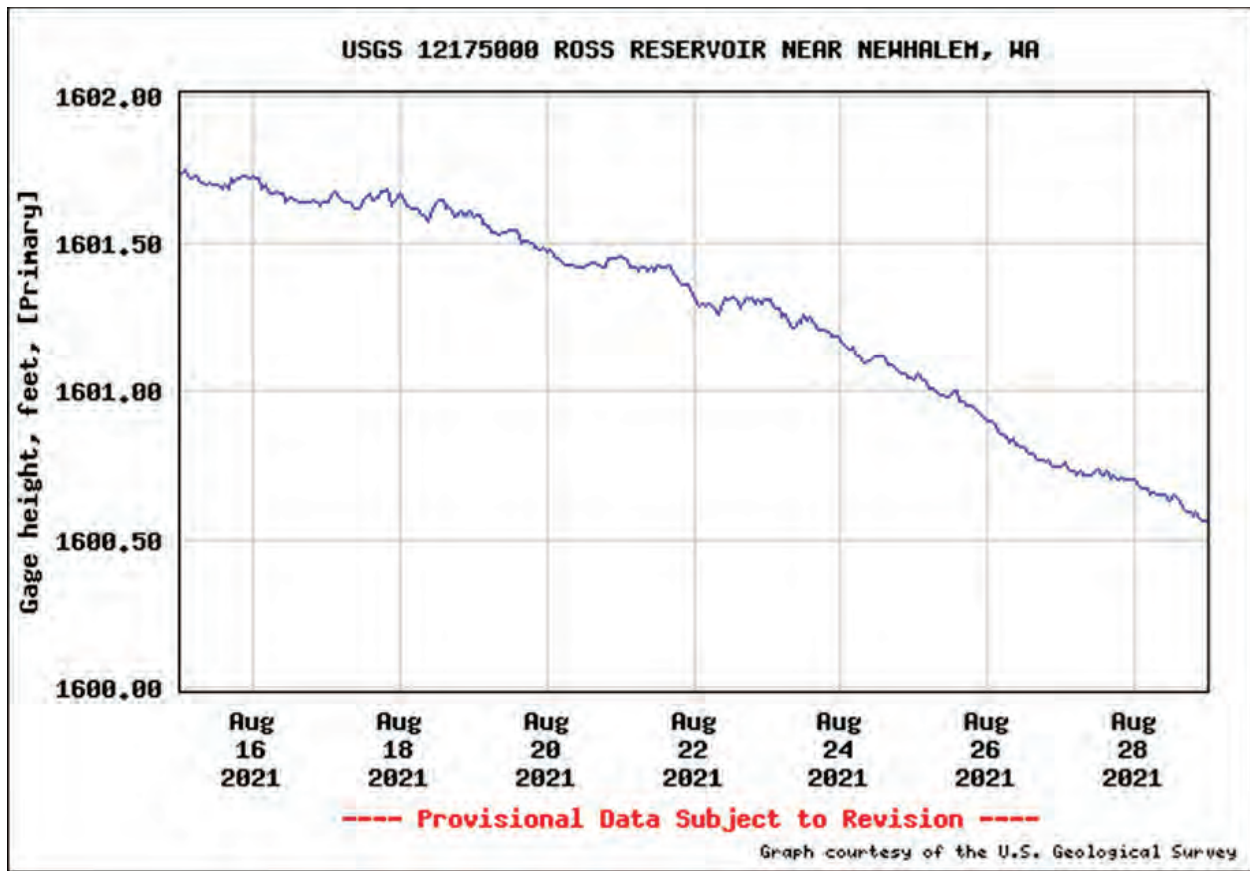


Figure 4.3-4. Example WSE (feet above CoSD) plot at Ross Dam evaluated to estimate the rate of WSE change (USGS 2022a).

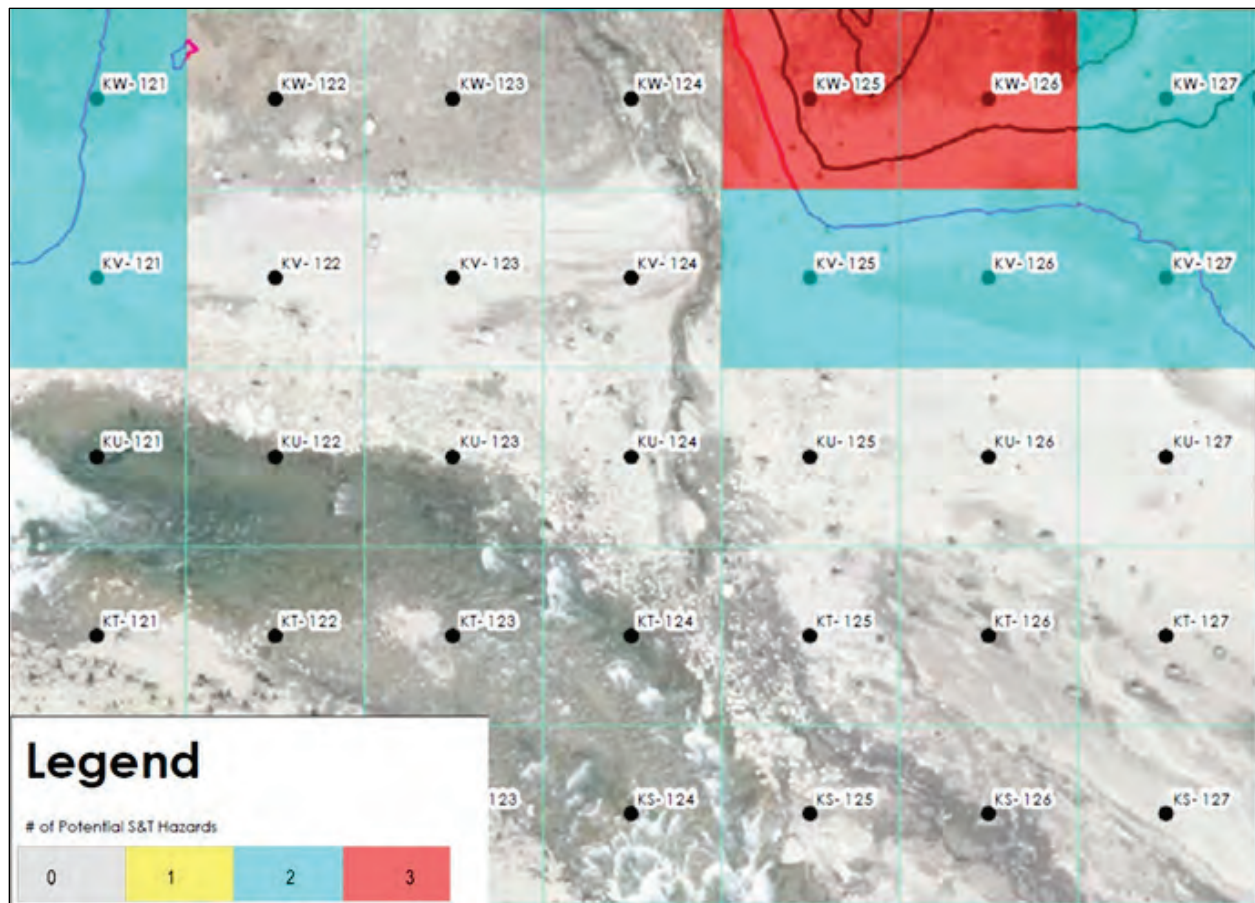


Figure 4.3-5. Area around mouth of Big Beaver Creek, showing overlaid quadrats, color coded by potential stranding and trapping group as determined from GIS-analyses. Contour lines indicate projected WSE for a potential field survey.

Fifth, the elevation-stratified quadrats within each sampling area were secondarily stratified into the four groups described above (Low Slope, Sink, Both, None), and quadrats within each group were randomly subsampled. This random subsampling was designed to provide a list of starting locations for the ACS field sampling approach that covered at least 10 percent of the total stratum. This design ensured that within each sampling area at least 10 percent of the recently dewatered shoreline habitat containing features that may present a fish stranding or trapping risk was sampled. This approach provides the following statistical power depending on landscape level prevalence of stranding and trapping events:

- 97 percent probability of detecting at least one stranding or trapping event, if stranding or trapping occurs within 30 percent of available risk features.
- 90 percent probability of detecting at least one stranding or trapping event, if stranding or trapping occurs within 20 percent of available risk features.
- 68 percent probability of detecting at least one stranding or trapping event if stranding or trapping occurs within 10 percent of available risk features.

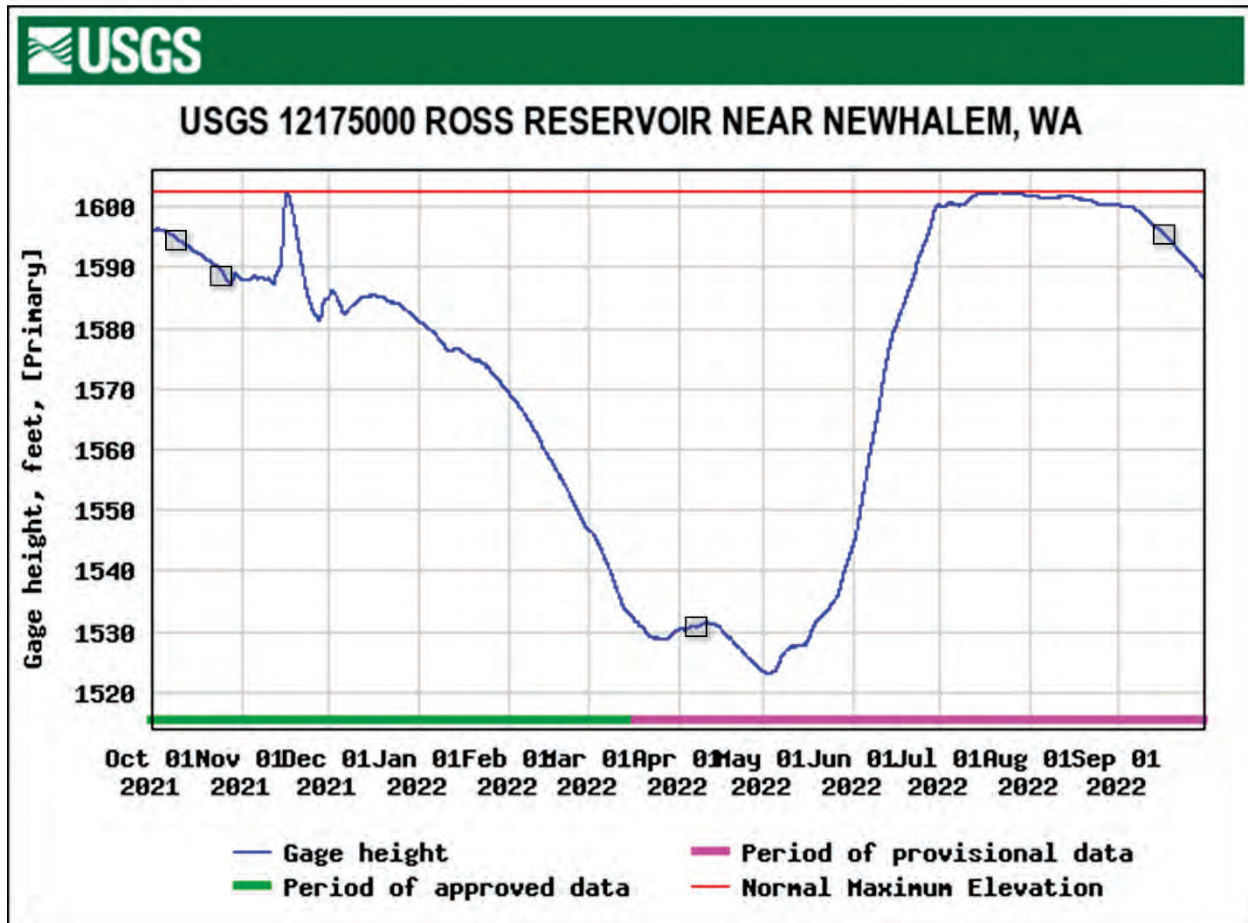
Using these SRS starting points, an ACS approach was then employed in the field to survey for potential stranding and trapping features, generally following the methods outlined by Thompson (1990):

Adaptive cluster sampling begins in the usual way with an initial sample of quadrats selected by simple random sampling with replacement, or simple random sampling without replacement. When one of the selected quadrats contains the organism of interest, additional quadrats in the vicinity of the original quadrat are added to the sample.

The method is akin to hunting for mushrooms—when a forager finds one of a desired species, effort is typically increased in the immediate area of the finding because a higher density of the species is likely. If any features were found, and the ACS approach was used to document neighboring features, greater than 10 percent of the stratum was sampled.

4.3.1.2 Ross Lake 2021-2022 Field Survey Methodology

Ross Lake was sampled four times during 2021-2022 (Figure 4.3-6). Surveys were designed to encompass as much of the drawdown range as feasible while also targeting periods when fish activity is expected to be greatest (e.g., during fall lake turnover and during late winter/early spring juvenile fish emergence). Two surveys were conducted in fall 2021 and one in spring 2022, using the ACS method described above. One additional, opportunistic survey was conducted in September 2022, using the more comprehensive (census) reconnaissance approach described in Section 4.1.1 because the areas exhibiting stranding and trapping features are limited early in the drawdown cycle making such census technique feasible. At the time of each field survey, efforts focused on sampling areas with many exposed potential stranding and trapping features, and these areas were surveyed by foot. Areas with minimal exposed features were evaluated rapidly, in some cases from the boat. If these areas appeared to contain dewatered features that could strand or trap fish, they were surveyed by foot.



Note: Water surface elevation presented in feet above CoSD. Shaded rectangular boxes indicate approximate periods of field surveys. Figure from USGS (2022a).

Figure 4.3-6. Ross Reservoir (i.e., Ross Lake) WSE from October 2021 through September 2022.

For each sampled quadrat, a field data form, developed using ArcGIS Survey123 (ESRI), was completed using a mobile device or field tablet (Figure 4.3-7). Data collected at each site included date and time of observations, environmental conditions, observers, quadrat ID, location coordinates, and photo documentation. If live or dead fish were observed, then they were counted (as possible) by species and life stage, and a photograph was taken. If evidence of fish predators or scavengers (e.g., bird tracks or identifiable fish remains) was observed, then a photograph was taken and a description of the evidence recorded. If either fish or evidence of fish predation was observed, then the stranding or trapping feature was surveyed for length, width, and maximum depth. To ensure an appropriate level of precision for geolocating field observations, field crews were equipped with Bluetooth-ready, surveyor grade, external antennas, capable of real-time 1 meter accuracy, using both GPS and GNSS antennas.

PSTZ Data Form

To be filled out at each potential stranding or trapping zone.

Date and Time*

Date: 10/28/2021 Time: 04:02 PM

Reservoir and Study Area*

Enter Study Area name in notes if selecting "Other"

Please Select

Weather*

Enter weather in notes if selecting "Other"

☐ Clear
☐ Partially Cloudy
☐ Cloudy
☐ Rain
☐ Snow
☐ Wind
☐ Other

FPE Staff*

☐ Belcher, Lindsay
☐ Caldwell, Lucas
☐ Hagman, Ben
☐ Koons, Elliot
☐ LaHara, Joel

SCL Staff

Please enter SCL staff as Last Name, First Name

1000

Quadrat ID*

Location*

Find address or place

No geometry captured yet.

Study Area Photo*

Select image file

Bearing of photo view*

90°

Distance from PSTZ to open water*

Please enter the distance in feet.

90°

Predator Indicators Present?*

☐ Yes
☐ No

Predator Indicators Description

1000

Predator Indicators Photo

Select image file

Fish Present?

"Yes" includes Live or Mort

☒ Yes
☐ No

PSTZ Length

Please enter the PSTZ length in feet.

100

PSTZ Width

Please enter the PSTZ width in feet.

100

PSTZ Max Depth

Please enter the PSTZ max depth in feet.

100

Stranded Fish Species 1

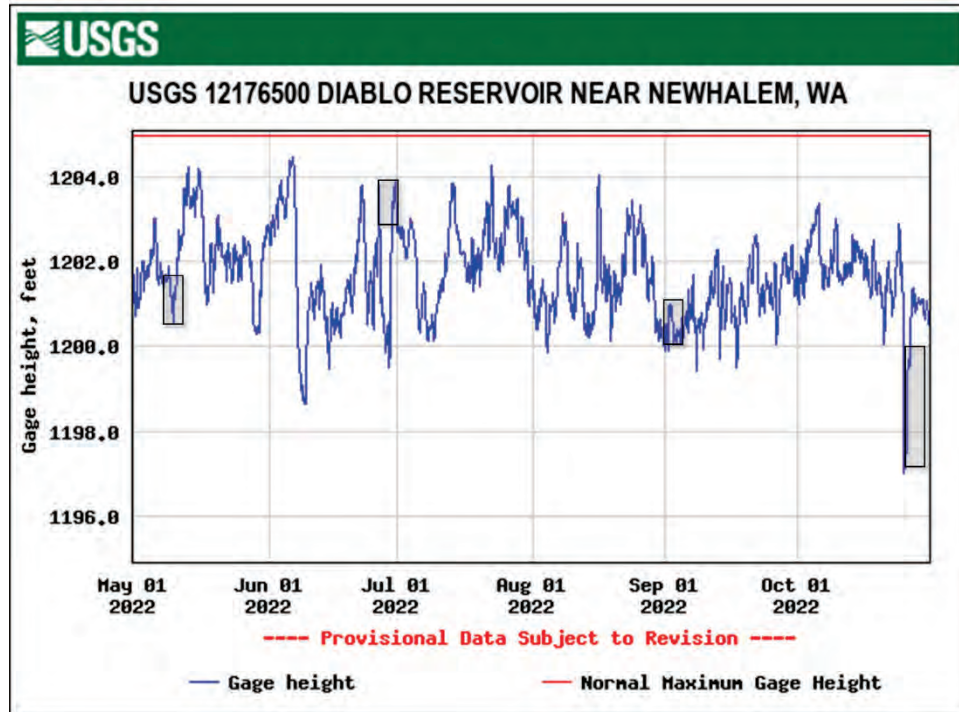
Enter fish species if selecting "Other"

☐ Rainbow Trout
☐ Bull Trout
☐ Brook Trout
☐ Redside Shiner

Figure 4.3-7. Survey data field form for use with tablet or mobile device.

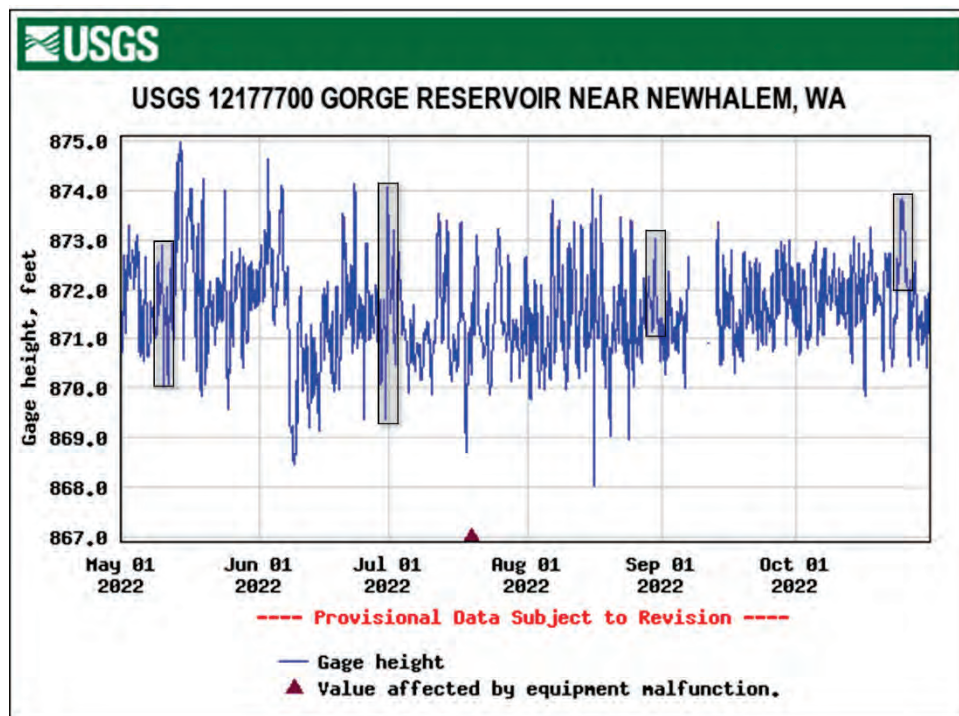
4.3.2 Diablo and Gorge Sampling Design

Sampling in Diablo and Gorge lakes included four surveys of areas exposed during normal Project operations between May and October 2021 (Figures 4.3-8 and 4.3-9). These surveys followed an alternative, transect-based approach to comprehensively survey areas previously identified as possible high-risk for stranding or trapping. On the days immediately prior to each sampling effort, reservoir WSE was assessed by checking the respective gage readings to identify potential stranding or trapping features that may be exposed. Then, on the day of the planned survey, field staff navigated to locations around each reservoir by truck or boat and surveyed as much of the exposed shoreline as possible on foot. During each survey, GPS data were collected to document the spatial extent of the survey, and the locations of any potential stranding and trapping features or stranded and trapped fish.



Note: Water surface elevation presented in feet above CoSD. Shaded rectangular boxes indicate approximate periods of normal operations field surveys. Figure from USGS (2022b).

Figure 4.3-8. Diablo Reservoir (i.e., Diablo Lake) WSE from May through October 2021.



Note: Water surface elevation presented in feet above CoSD. Shaded rectangular boxes indicate approximate periods of reconnaissance surveys. Figure from USGS (2022c).

Figure 4.3-9. Gorge Reservoir (i.e., Gorge Lake) WSE from May through October 2021.

5.0 RESULTS

5.1 Reconnaissance Surveys

As described in Section 4.1, the purpose of the reconnaissance surveys was to identify and refine survey areas around Ross Lake, refine spatial sampling and survey methodology, identify access and logistics, and optimize order and seasonality of sampling. These surveys were not conducted to generate data that would be useable within an analytical framework for evaluating stranding and trapping risk. This section focuses on results pertaining to the intended purpose of these surveys, while also providing anecdotal information collected opportunistically, when illustrative or otherwise appropriate. Lessons learned during these surveys, summarized in Section 5.3, were used to adaptively update the survey plan so that efforts could focus on surveying at times when and in places where the likelihood of documenting stranding and trapping was greatest.

5.1.1 Ross Lake Reconnaissance

5.1.1.1 December 2020 Ross Lake Survey

No stranding events, dead fish, or evidence of predation were observed within any of the areas sampled along the eastern shore of the north end of Ross Lake. Crews noted that many of the sampled areas had been out of the water for an extended period and that sampling less than 1 percent of the entire dewatered varial zone would be feasible. The extent of exposed survey area required a modification of grid cells surveyed, stratified to examine cells most recently exposed, as described in Section 5.1.3.2.

5.1.1.2 March 2021 Ross Lake Survey

All sites surveyed around the mouth of Roland Creek were characterized by steep banks without appreciable depressions such as from tree wells. Sites around the mouth of Big Beaver Creek exhibited low potential for stranding or trapping. At the water's edge when this area was sampled (Figures 4.1-1 and 4.1-2C), the banks exhibited a consistent downhill gradient towards the lake, with minimal depressions. Sites around the mouth of Lightning Creek exhibited low slope areas but not many tree wells or other depressions. The area around Lost Lake was characterized by low slope and many tree well depressions. In the area around Ruby Arm, crews observed no evidence of stranding or trapping. Of the areas surveyed during the March 2021 visit, the area around Lost Lake appeared to present the greatest potential for stranding or trapping—the area primarily represents a large stranding plane though several potential trapping sites were also observed. These trapping sites were found also to be identified through the preliminary DEM coverage developed to guide the survey using the ACS approach stratified closer to the shoreline. Tree wells were relatively limited in comparison to the north end of the lake and, as identified in April 2021, the confluence zones of Little Beaver and Arctic creeks.

5.1.1.3 April 2021 Ross Lake Survey

No evidence of stranding or trapping was observed in sites surveyed around the mouth of Lightning Creek or around Lost Lake. At sites around the mouth of Little Beaver, crews observed more potential stranding and trapping sites than during the March 2021 survey. These were characterized as undulating low-slope terrain with depressions that were holding water or appeared to have previously held water. Sites around the mouth of Arctic Creek contained a large number of

potential trapping sites. At all sites surveyed during this visit, crews observed no evidence of stranding or trapping, including live fish, mortalities, or fish remains.

5.1.2 Opportunistic Diablo Lake Reconnaissance

On Wednesday, September 16, 2020, 13 stranding pools were identified in the Thunder Arm area, ranging in size from approximately 0.1 to 155 square meters (1 to 1,670 square feet). Ten of these pools contained no fish (Section 5.3.1). The other three pools contained one or two live, newly emergent Rainbow Trout fry that were approximately 2 centimeters (0.8 inches) long.

On Thursday, September 17, 2020, 26 potential stranding pools were identified in the Thunder Arm area, ranging in size from approximately less than 0.1 to 30 square meters (1 to 323 square feet). Nineteen of these pools contained no fish. Three pools contained one live 2-centimeter (0.8-inch) Rainbow Trout fry. One pool contained two live 2-centimeter (0.8-inch) Rainbow Trout fry. One pool contained a 5-centimeter (2-inch) live Rainbow Trout fry. One pool contained one live and one dead 2-centimeter (0.8-inch) Rainbow Trout fry. The remaining pool contained 14 dead 2-centimeter (0.8-inch) Rainbow Trout fry.

5.1.3 Lessons Learned During Reconnaissance

Key takeaways from the field reconnaissance effort, which was used to inform future sampling, are summarized below.

5.1.3.1 Areas with High Potential for Stranding and Trapping

Eight areas around Ross Lake were identified as exhibiting topographic characteristics that may present high risk for stranding and trapping at certain WSE within normal operations (Figure 3.0-1). These areas were primarily shallow gradient alluvial fans located near the mouth of tributaries flowing into Project reservoirs. Others were low gradient reaches characterized by a high density of relict stumps that have been eroded to form depressions within the surrounding sediment (tree wells). Input from LPs was taken into consideration during this process as well. For example, the Ruby Arm of Ross Lake does not contain a high concentration of low slope or depressional features; however, NPS suggested that this area may pose a high stranding or trapping risk. Therefore, it was included in investigations.

The opportunistic survey on Diablo Lake indicated that the Thunder Arm reach presents a stranding and trapping risk when reservoir elevations are rapidly drawn down from WSE of approximately 1,209.4 feet NAVD 88 (1,203 feet CoSD) to WSE below approximately 1,207.4 feet NAVD 88 (1,201 feet CoSD), at least in September when the event occurred (Figure 4.1-3).

5.1.3.2 Refinements to Survey Methodology Based on 2020 and 2021 Reconnaissance Surveys

As envisioned by the RSP, methods were refined for navigating to survey starting locations, establishing survey quadrats, measuring features, and collecting data (City Light 2021). Crews developed systems and adopted technology such as handheld tablets equipped with georeferenced PDF maps and navigation software, which increased survey efficiency and enabled surveying more sites. In addition, refinements to the spatial stratification of the varial zone and the field survey methodology were made to focus efforts on sampling as much recently dewatered habitat as possible, to provide the greatest likelihood of observing stranding and trapping.

The initial approach to spatial sampling was based on sampling 10 percent of the exposed varial zone within each survey area. During the first reconnaissance surveys on Ross Lake, it became clear that this was not logistically feasible and led to sampling large extents of the varial zone that had been dewatered for extended periods where observing stranding and trapping was not likely. Stratifying the varial zone by elevation range would allow field crews to focus on the portion of the varial zone that was recently dewatered, and thus had a greater likelihood of containing actively stranded and trapped fish. Consequently, a process was developed for stratifying each survey area based on predicted WSE at the time of sampling and presence of potential stranding and trapping features, before randomly selecting starting locations from these nested strata (as described in Section 4.3.1.1). The number of attributes of potential stranding and trapping surveys to be measured in the field was reduced to focus on topographic features and evidence of fish stranding and trapping. This ensured that field data focused on achieving the study's primary objective of testing the GIS analyses (i.e., the DEM) to develop robust estimates of the stranding and trapping risk areas around each reservoir.

Crews visually surveyed each randomly selected 25-meter square quadrat within a given study area, by fixing the centroid of the quadrat and extending a field tape from this location 12.5 meters and visually surveying while survey within this a 25-meter circle around the centroid of the quadrat, the survey starting location. To address the small area near the corners of square quadrats that this approach would miss (i.e., by inscribing a 25-meter circle within a 25-meter square), crews extended the survey zone by approximately 5 meters beyond the circumference. The number of attributes of potential stranding and trapping surveys to be measured in the field was reduced to focus on topographic features and evidence of fish stranding and trapping. This ensured that field data focused on achieving the study's primary objective of testing the GIS analyses (i.e., the DEM) to develop robust estimates of the stranding and trapping risk areas around each reservoir.

5.1.3.3 Logistics

Accessing the northern end of Ross Lake is challenging when the reservoir is near its annual minimum WSE. When Ross Lake WSE was approximately 1,510.8 feet NAVD 88 (1,504.5 CoSD), accessing the northern reaches near the U.S.-Canada border was not possible with the City Light boat due to shallow and fast-moving water and an abundance of exposed stumps.

5.1.3.4 Survey Timing

Surveying Ross Lake throughout the range of normal operations is important to capture potential stranding and trapping features that emerge at different WSE. For example, the challenges in accessing the northern end of the lake under low WSE that were described above, plus the observation that potential stranding and trapping features in this area exist at elevations that are dewatered shortly after drawdown begins, means that these reaches need to be prioritized for sampling early during drawdown. Additionally, near full pool elevations a broad, low gradient bench of littoral zone habitat containing many features that could strand or trap fish is present, primarily along the northern shoreline (see section 5.2, Figures 5.2-1 and 5.2-2, below). However below this bench the shoreline precipitously drops off towards the limnetic zone of lake. This means that within this area, a band of low-gradient varial zone habitat that could present stranding and trapping risk is exposed under a relatively narrow range of WSE. As such, this elevation band at this location where these stranding and trapping features exist represents what would be termed 'problem water elevations' (PWEs) and efforts to sample this PWE zone targeted periods when

the WSE is within this range. Other zones where stranding and trapping features are exposed, such as the littoral fringe area around Lost Lake, are completely inundated until the reservoir is drawn down to much lower WSE. It was determined that crews could subsample a greater proportion of potentially high-risk areas by focusing on recently dewatered areas, at the scale of both the survey areas and the quadrats within each survey area.

Surveys on Diablo and Gorge lakes were proposed to be performed quarterly according to the RSP. However, this plan was refined based on fish periodicity information, to target times of the year when fish were more likely to be present and observable. Consequently, the Q1 survey was shifted to occur during Q2, and thus two surveys were conducted in Q2, one in Q3 and one in Q4.

5.2 Desktop Analyses

5.2.1 Analysis of DEMs for Stranding and Trapping Risk

5.2.1.1 Ross Lake

Across the entirety of Ross Lake, there was a total of 2,627.3 acres of low slope areas and 622.6 acres of sinks (Figure 5.2-1). The low slope areas mostly occurred between the northern limit of the reservoir and the mouth of Lightning Creek. Low slope areas were distributed relatively evenly by elevation band, with the highest amount in the upper 25 percent of the normal WSE range (above approximately 1,577.3 feet NAVD 88 [1,571 feet CoSD]) (Table 5.2-1; Figure 5.2-2). By contrast, the greatest concentration of sink area was in the lowest 25 percent of normal WSE (below approximately 1,513.3 feet NAVD 88 [1,507 feet CoSD]) (Table 5.2-1; Figure 5.2-3). Both low slope and sink totals in the lowest elevation percentile are likely underestimates of the true acreage, as the lower limit of the DEM was 13.5 feet above the normal operating minimum WSE for Ross Lake. This missing elevation stratum is below the limit of what is typically dewatered (1,541.26 feet NAVD 88 [1,535 feet CoSD]; see Section 3.0).

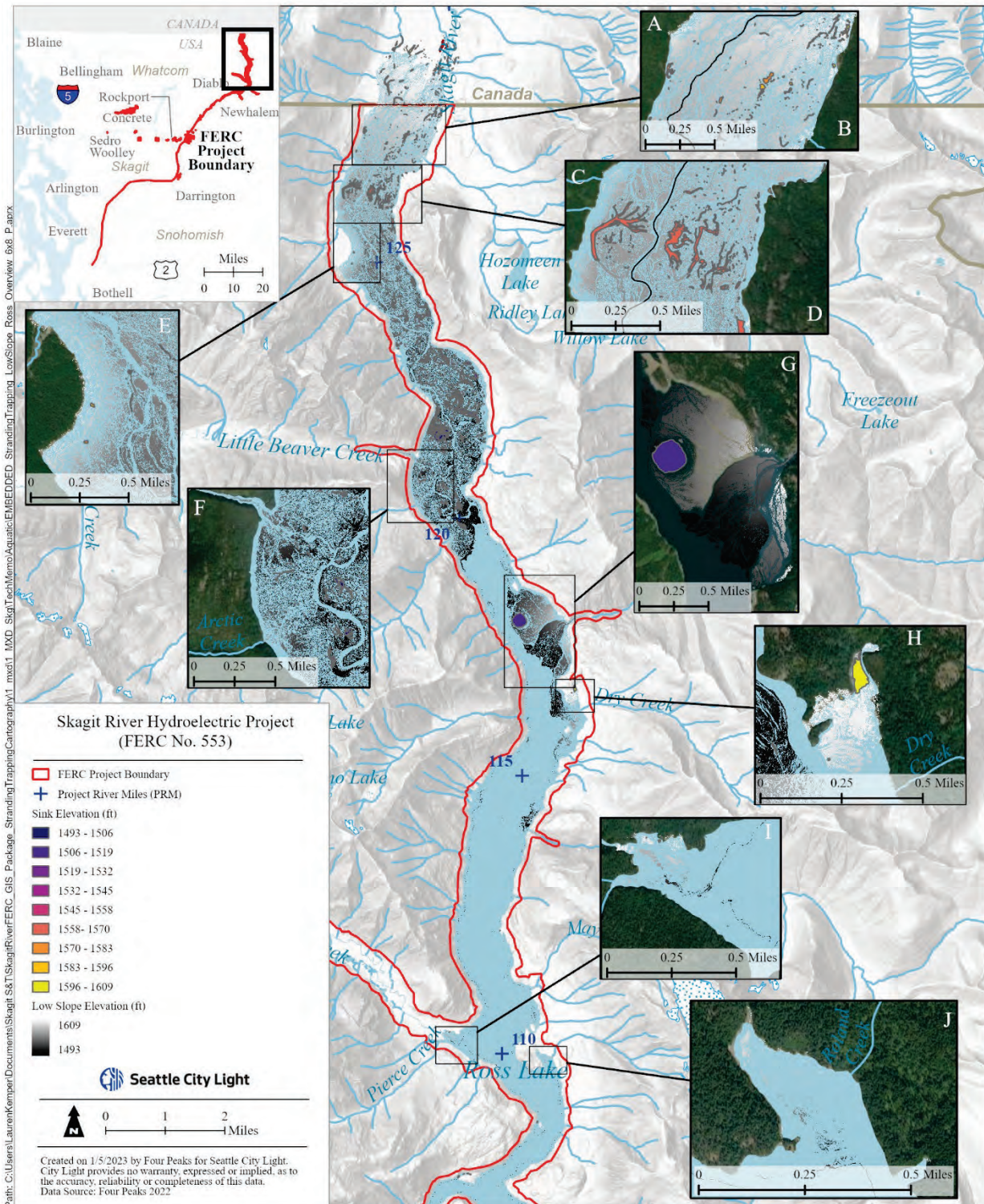
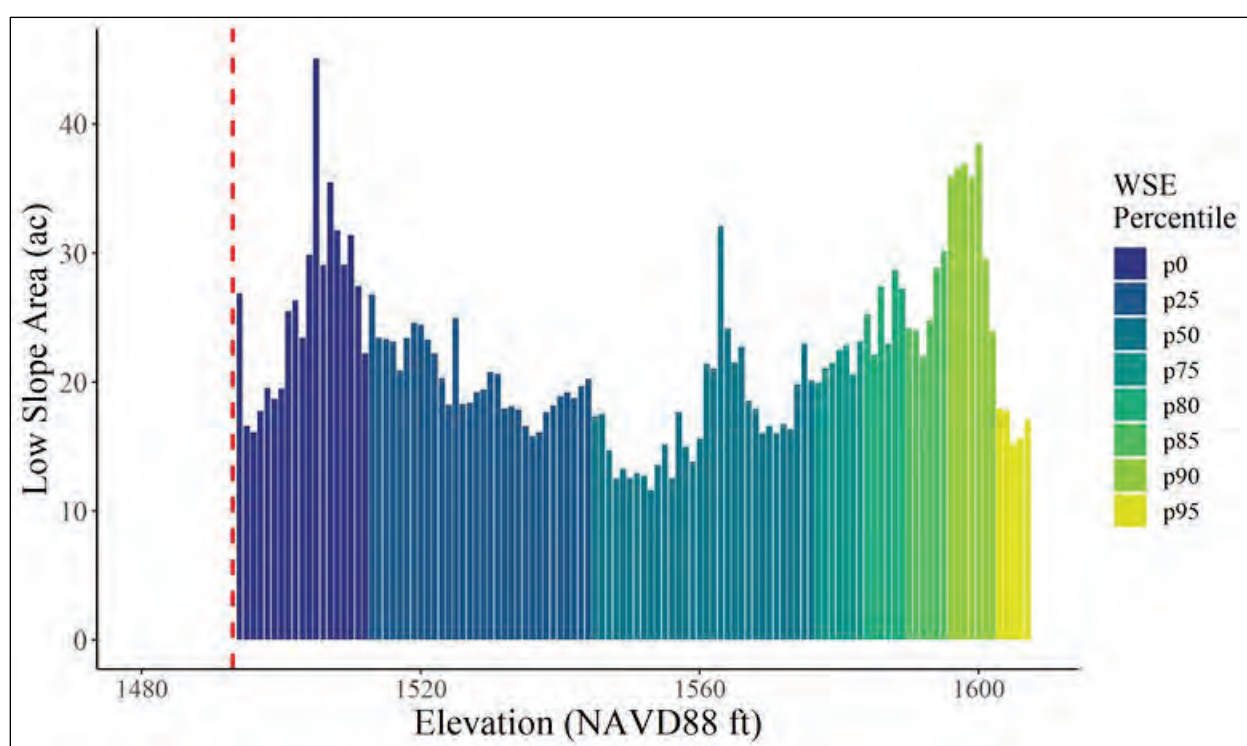


Figure 5.2-1. Overview map of surveys conducted around Ross Lake, displaying low slope and sink areas.

Table 5.2-1. Ross Lake potential stranding (low slope) and trapping (sink) areas by WSE percentile.

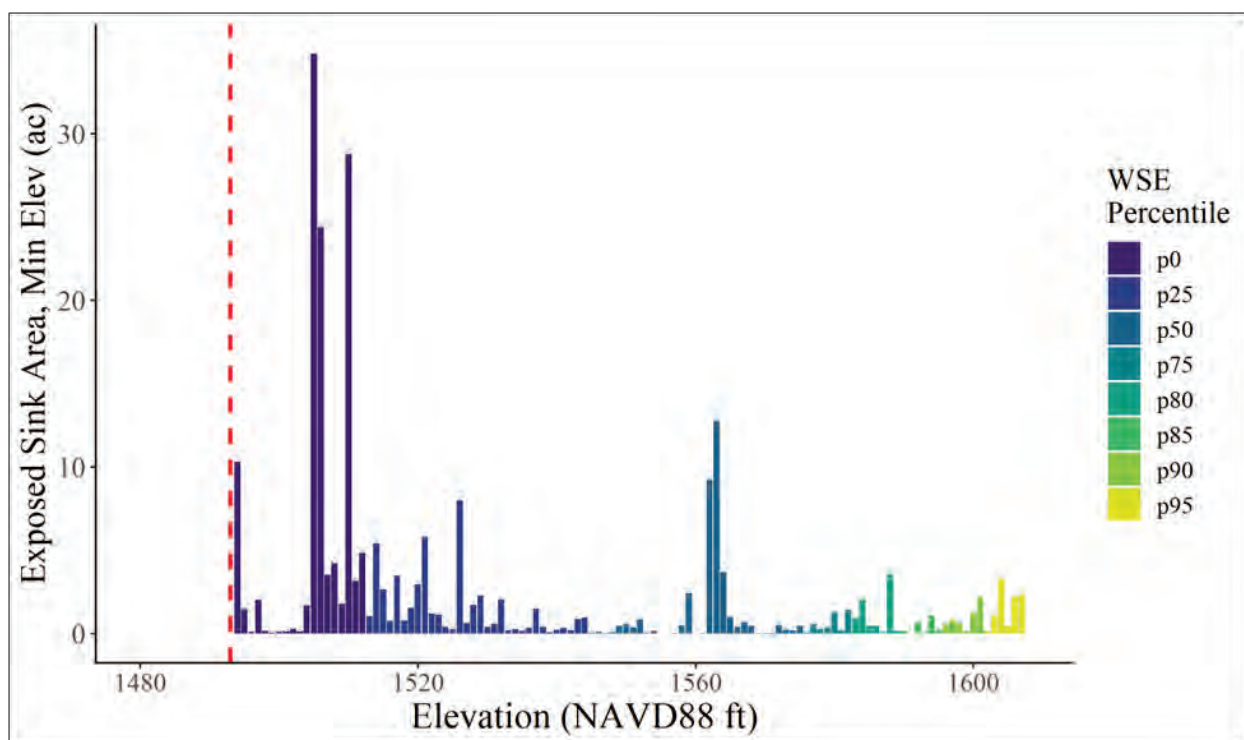
Elevation Percentile	Elevation Range (NAVD 88)	Low Slope Area Exposed (acres)	Sink Area Exposed (acres)
75	1,576.8-1,608.8	791.8	30.1
50	1,544.8-1,576.8	552.8	35.9
25	1,512.8-1,544.8	661.2	49.1
0*	1,494.3-1,512.8	631.5	122.2

Note: The 0 WSE percentile extends to the normal operating minimum WSE for Ross Lake 1,480.8 NAVD 88 (1,474.5 feet CoSD); however, the DEM for Ross Lake only extends to 1,494.3 NAVD 88 (1,488 feet CoSD).



Bar colors represent water surface elevation (WSE) percentiles of low slope features in elevation bands within normal operations. Dashed red line represents the WSE at the time that the (terrestrial) LiDAR was flown.

Figure 5.2-2. Ross Lake low slope area in acres (ac) by elevation.



Bar colors represent water surface elevation (WSE) percentiles of sinks in elevation bands within normal operations. Dashed red line represents the WSE at the time that the (terrestrial) LiDAR was flown.

Figure 5.2-3. Ross Lake sink area in acres (ac) by elevation.

5.2.1.2 Diablo and Gorge Lakes

Within the varial zone of the Thunder Arm of Diablo Lake, the total low slope area was 32.2 acres, and the total sink area was 2.5 acres. (Figure 5.2-4). Both low slope features and sinks were concentrated within elevation strata that are within or below the lowest quartile of the normal operational range of WSE (Table 5.2-2, Figure 5.2-5, Figure 5.2-6). The greatest concentration of low slope area is within the elevation stratum between 1,203.4-1,206.4 feet NAVD 88 (1,197-1,200 feet CoSD), which is at the low end of the normal operational range of WSE within Diablo Lake, below what is typical. Within the Thunder Arm, stranding and trapping features were concentrated above the SR 20 bridge. In this upper half of the inlet, the majority of the varial zone presents a stranding or trapping risk at some WSE. As Diablo Lake WSE is lowered past 1,207.4 feet NAVD 88 (1,201 feet CoSD), a large sink or sinks in this part of Thunder Arm is exposed as Thunder Creek side channels are exposed and cut off from the mainstem thalweg.

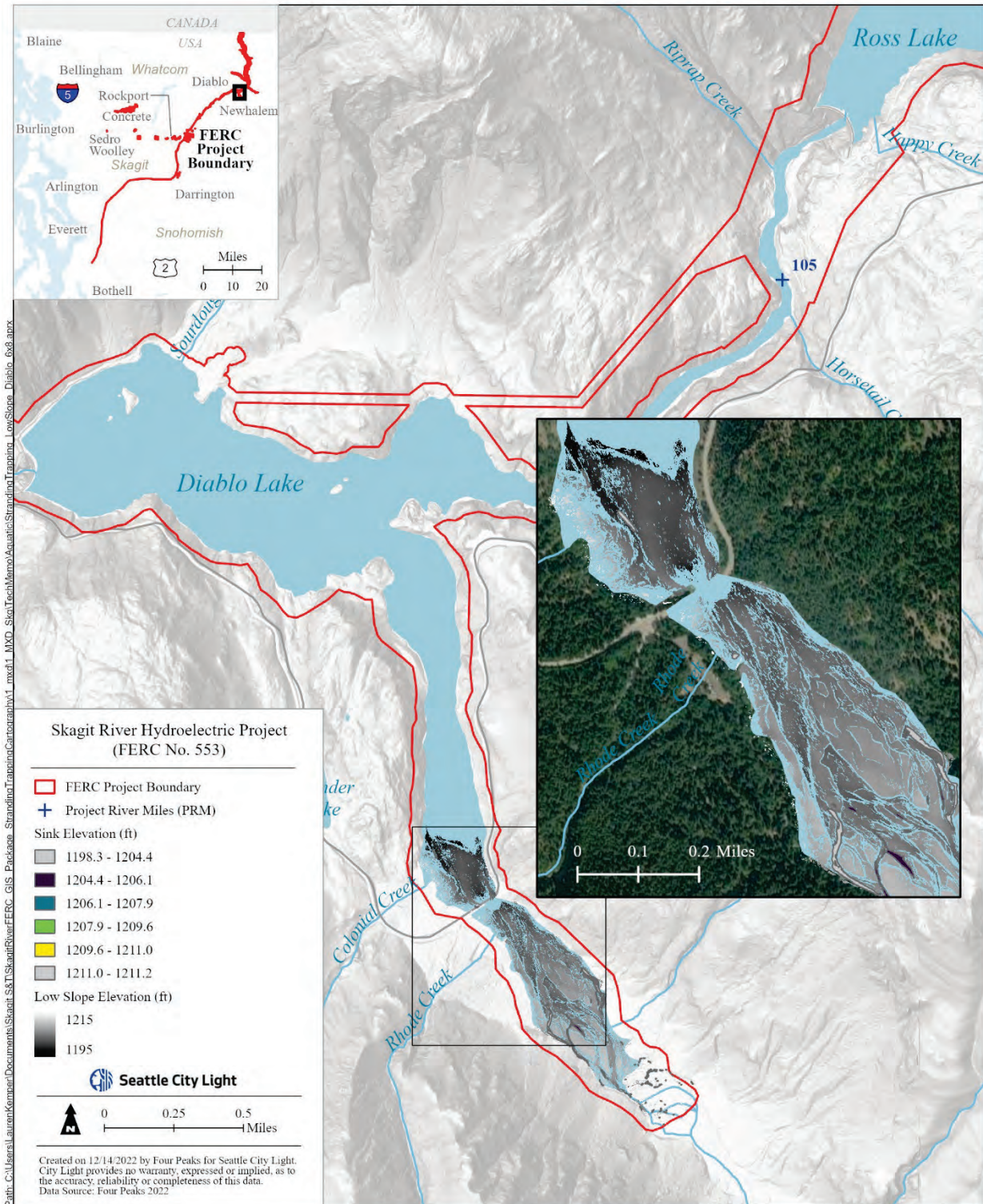
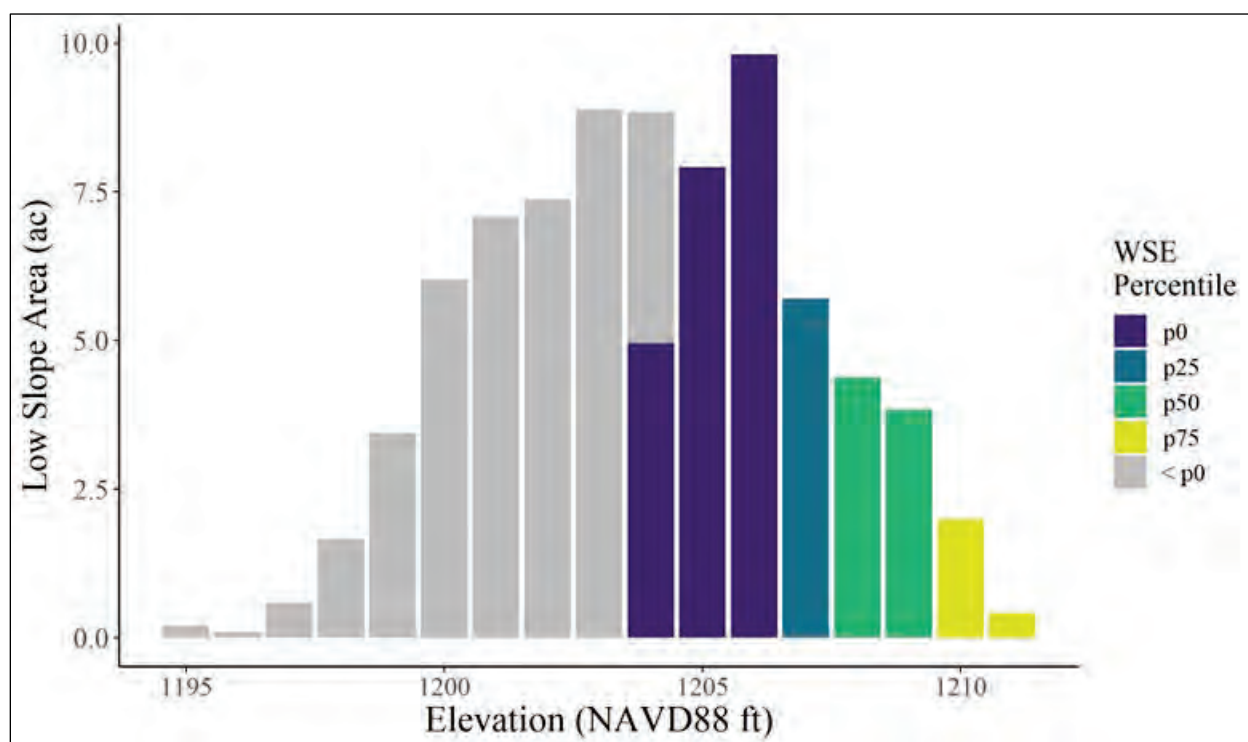


Figure 5.2-4. Diablo Lake overview of survey locations, displaying low slope and sink areas in Thunder Arm.

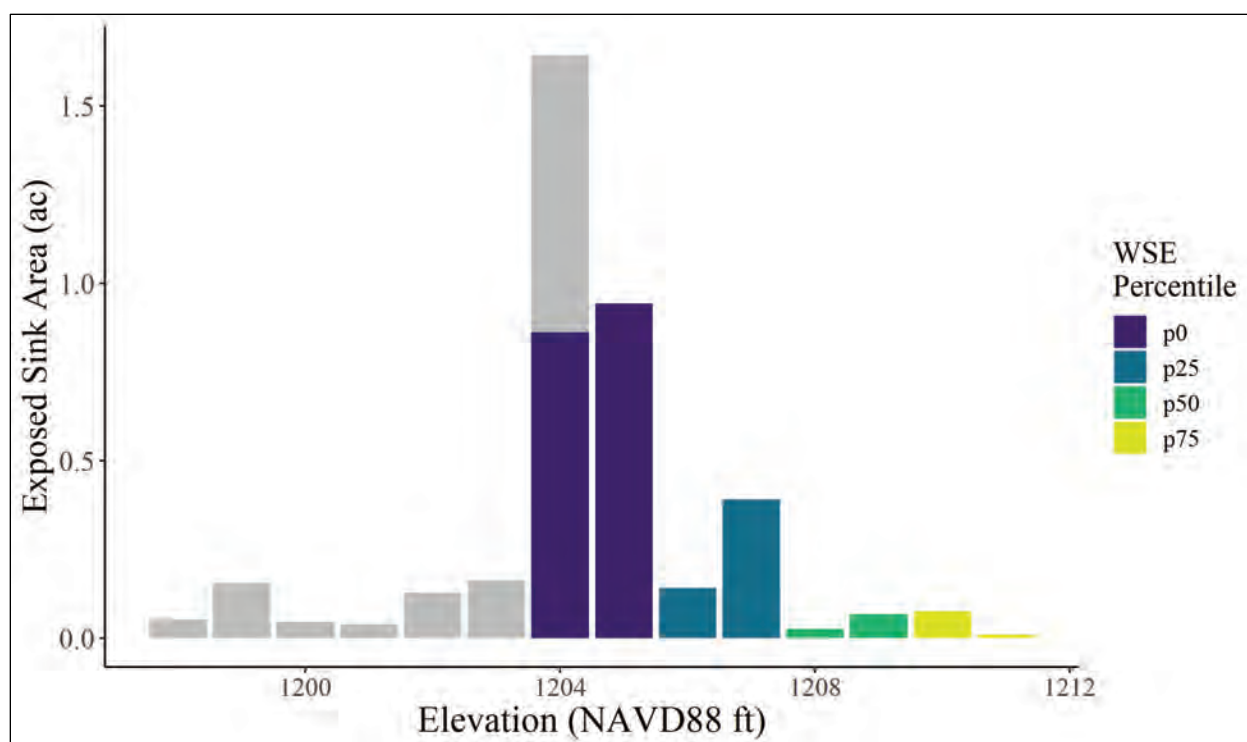
Table 5.2-2. Diablo Lake potential stranding (low slope) and trapping (sink) areas by WSE percentile.

Elevation Percentile	Elevation Range (feet NAVD 88)	Low Slope Area Exposed (acres)	Sink Area Exposed (acres)
75	1,209.6-1,211.4	2.1	0.1
50	1,207.9-1,209.6	7.0	0.1
25	1,206.1-1,207.9	4.8	0.5
0	1,204.4-1,206.1	18.4	1.8



Colors represent water surface elevation (WSE) percentiles of low slope features in elevation bands within normal operations, with gray representing low slope areas below normal operating minimum (1,204.4 feet NAVD 88). Stacked bar indicates greater precision of DEM compared to bin widths visualized.

Figure 5.2-5. Diablo Lake Thunder Arm low slope area in acres (ac) by elevation.



Colors represent water surface elevation (WSE) percentiles of sinks in elevation bands within normal operations, with gray representing sink area below normal operating minimum WSE (1,204.4 feet NAVD 88). Stacked bar indicates greater precision of DEM compared to bin widths visualized.

Figure 5.2-6. Diablo Lake Thunder Arm sink area in acres (ac) by elevation.

Within the varial zone of Gorge Lake, the total low slope area was 31.8 acres, and the total sink area was 10.7 acres (Figure 5.2-7). A data gap noted between approximately 868.5-877.5 feet NAVD88 (862-871 feet CoSD), which is an area between the limits of the topography developed from the 2018 green LiDAR and 2022 bathymetry, is an area where slope and sink analyses were not possible. This data gap extends 1 foot into the normal operating range of Gorge Lake, so data quality impacts were minimal.

Both low slope features and sinks were concentrated within elevation strata near the top end of the operational range of WSE (Table 5.2-3, Figure 5.2-8, Figure 5.2-9). The greatest concentration of both low slope and sink areas are within the elevation stratum between 870.5-880.5 feet NAVD88 (864-874 feet CoSD), which is at the upper end of the operational range of WSE within Gorge Lake. Both low slope and sink features were concentrated in two general locations: immediately upstream of the SR 20 causeway and bridge, and near Reflector Bar adjacent to the town of Diablo.

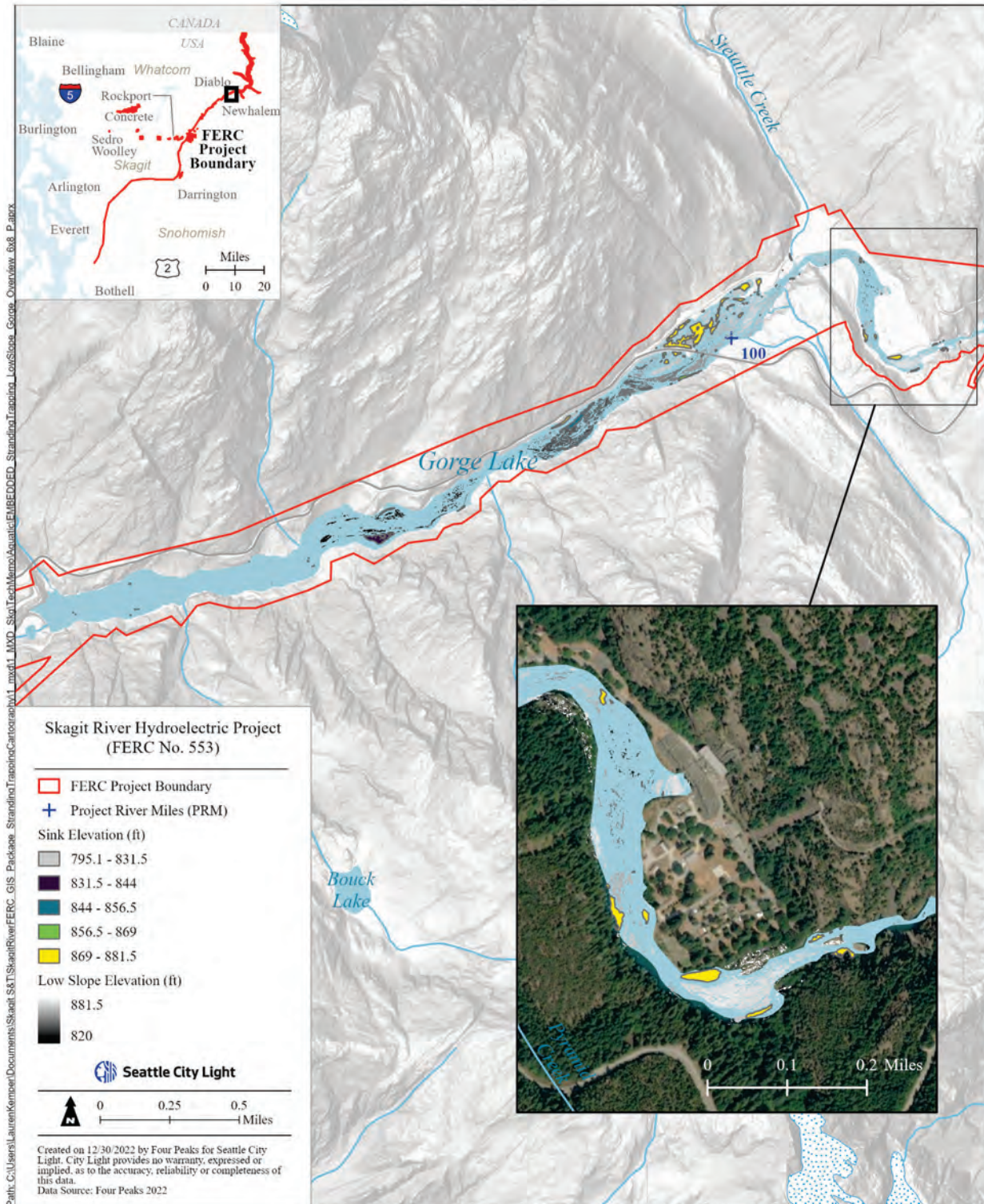
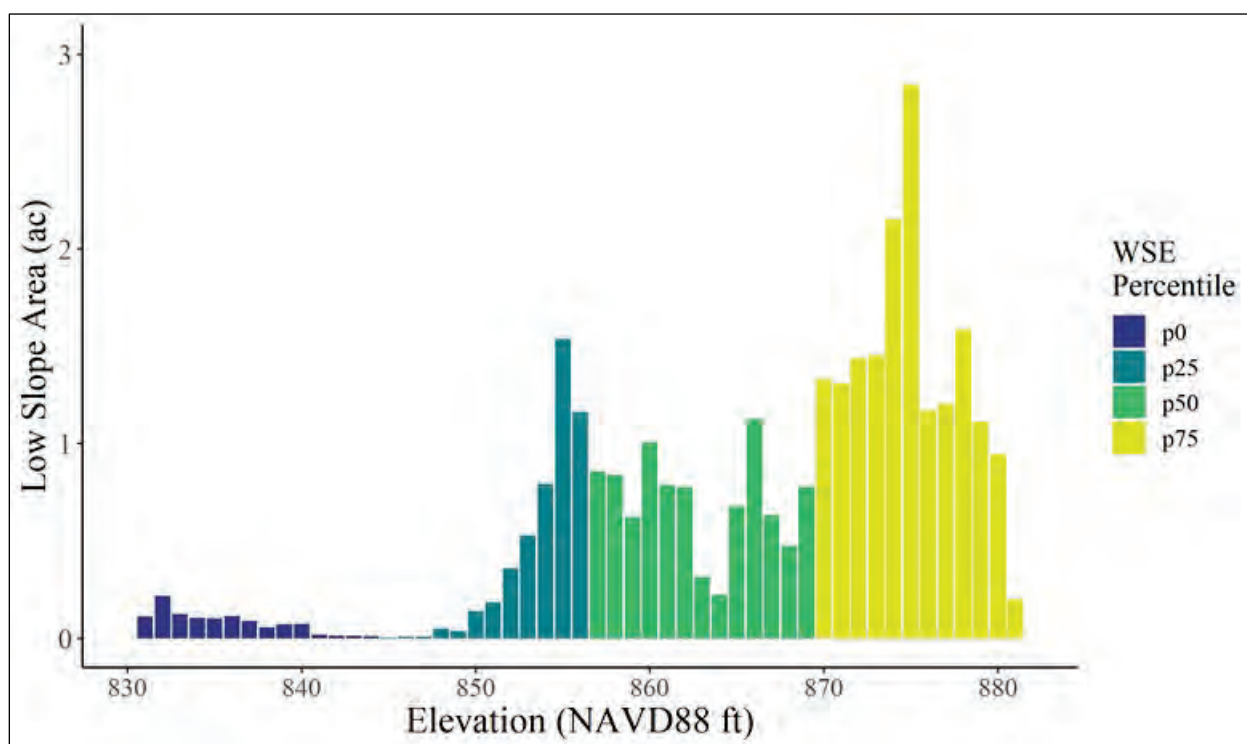


Figure 5.2-7. Gorge Lake overview of survey locations, displaying low slope and sink areas.

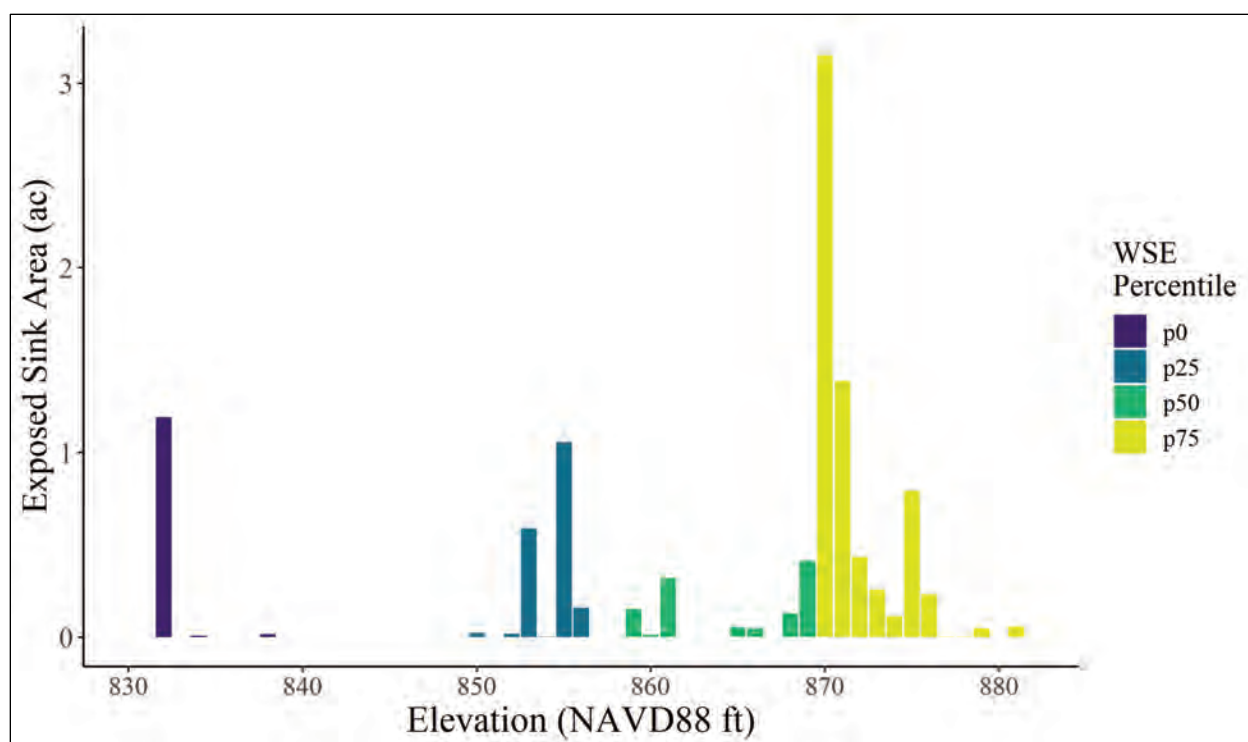
Table 5.2-3. Gorge Lake potential stranding (low slope) and trapping (sink) areas by WSE percentile.

Elevation Percentile	Elevation Range (feet NAVD 88)	Low Slope Area Exposed (acres)	Sink Area Exposed (acres)
75	869.0-881.5	16.7	6.8
50	856.5-869.0	9.1	0.9
25	844.0-856.5	4.8	1.8
0	831.5-844.0	1.1	1.2



Colors represent water surface elevation percentiles of low slope features in elevation bands within normal operations.

Figure 5.2-8. Gorge Lake low slope area in acres (ac) by elevation.



Colors represent water surface elevation percentiles of sinks in elevation bands within normal operations.

Figure 5.2-9. Gorge Lake sink area in acres (ac) by elevation.

5.2.2 Analysis of Reservoir Drawdown

As described in Section 4.2.2, the purpose of the reservoir drawdown analysis is twofold. First, this analysis was used to inform survey planning. Understanding the pattern of WSE, refill, and drawdown throughout the year is important for determining when to sample areas around the reservoirs. Second, this analysis contextualizes stranding and trapping observations in the field by characterizing the timing, frequency, and duration of exposure of features throughout the reservoir that could present a risk to fish.

5.2.2.1 Ross Lake

Ross Lake WSE between 2011 and 2021 ranged between 1,487.5 and 1,608.8 feet NAVD 88 (1,481.2 and 1602.5 feet CoSD, Table 5.2-4 and Figure 5.2-10).

Table 5.2-4. Ross Lake WSE statistics (2011 to 2021).

Statistic	WSE (feet NAVD 88)
Minimum	1,487.5
Maximum	1,608.8
Median	1,583.0
Mean	1,575.0
Range	121.3

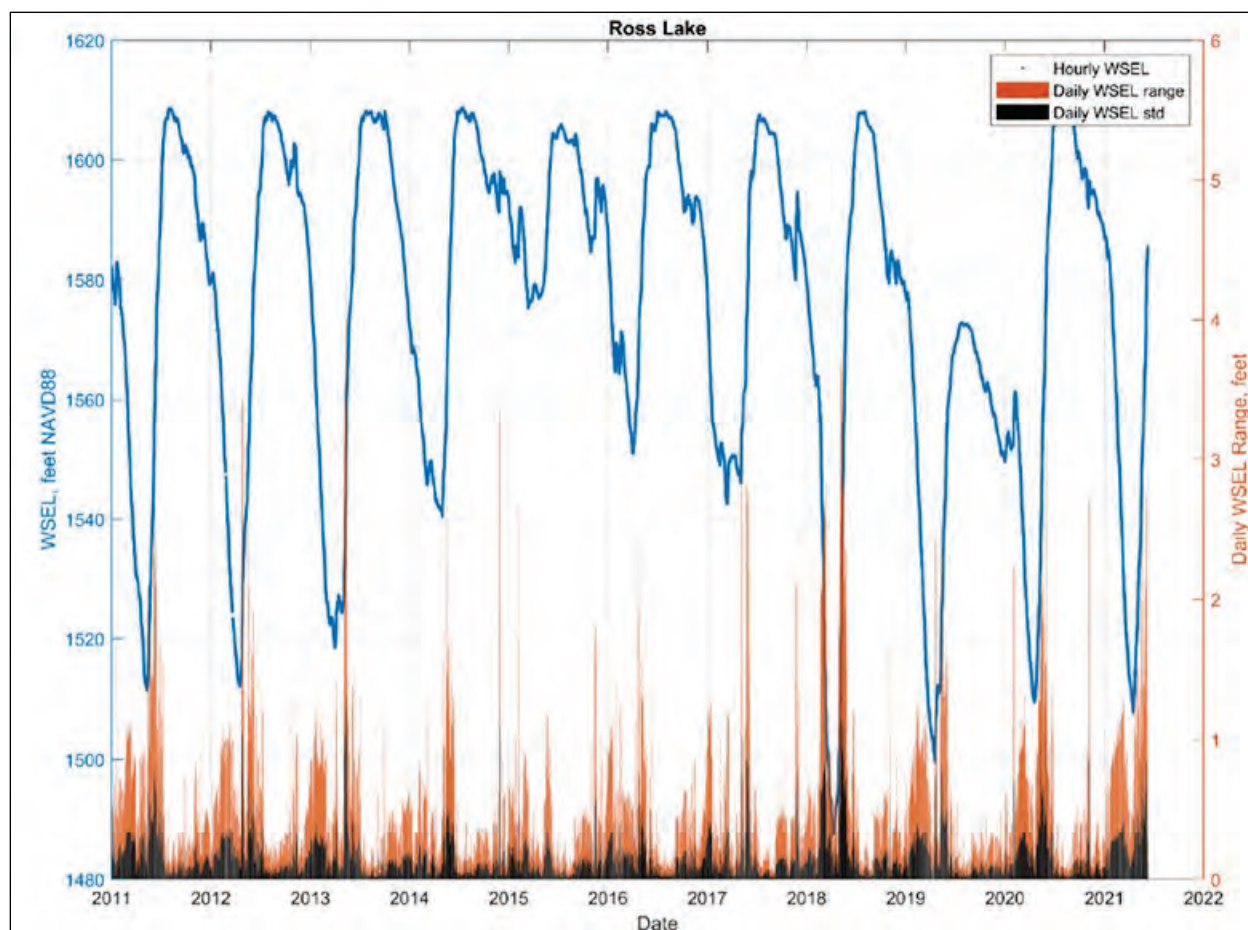


Figure 5.2-10. Ross Lake WSE time series (2011 to 2021).

In general, Ross Lake does not exhibit substantial daily fluctuations within the normal operating range and daily changes in WSE tend to be on the order of 0.5 feet (Figure 5.2-10) (mean = 0.56 feet, median, 0.39 feet, standard deviation = 0.55, minimum = 0.03 feet, maximum = 5.26 feet). Therefore, although daily (end of day) WSE were specified in the study plan, hourly gage heights were used in the analysis to better characterize WSE fluctuations on Ross Lake at a resolution sufficient to estimate the frequency at which trapping pools form and stranding areas become exposed.

The statistics by month for Ross Lake (Table 5.2-5) over the period of record indicate the lowest WSE occur during April after drawdown and before the spring melt-off occurs. Ross Lake is generally full or near-full by June, and WSE peaks during July and August before drawdown begins in the fall. Across the period of record, the greatest interannual variability in monthly averaged WSE occurs during the spring months from March to May, as the reservoir approaches its annual minimum and begins to refill.

Table 5.2-5. Ross Lake WSE (feet NAVD 88) statistics by month of year based on data from January 1, 2011 thru June 9, 2021.

Statistic	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Minimum	1,549.8	1,527.0	1,491.0	1,487.5	1,503.0	1,541.0	1,568.9	1,571.3	1,565.6	1,561.3	1,555.5	1,549.7
Maximum	1,593.3	1,592.2	1,584.5	1,579.3	1,599.0	1,608.1	1,608.8	1,608.5	1,607.8	1,608.2	1,602.8	1,597.5
Median	1,573.2	1,557.9	1,536.3	1,524.6	1,554.3	1,594.2	1,606.9	1,606.8	1,602.1	1,594.6	1,591.7	1,586.8
Mean	1,572.1	1,559.0	1,537.3	1,529.4	1,554.2	1,590.2	1,602.9	1,603.0	1,598.9	1,591.7	1,588.0	1,583.6
Variance	112.0	187.1	418.1	629.4	614.5	219.1	115.6	107.7	115.8	123.5	120.3	139.5
Range	43.5	65.2	93.5	91.8	96.0	67.1	39.9	37.2	42.3	46.9	47.3	47.9

The frequency of occurrence and percent exceedance curves for the full dataset from 2011 to 2021 are plotted in Figure 5.2-11. The plot shows the range of WSE within the record to be 1,488.3 to 1,609.3 feet NAVD 88 (1,482 and 1,603 feet CoSD). The most frequently occurring WSE in the record are between 1,606.3 and 1,608.3 feet NAVD 88 (1,600 and 1,602 feet CoSD). A similar exceedance and frequency of occurrence curve (Figure 5.2-12) is provided for the month of January to show an example of the month-of-year analysis. The range in one month is reduced, and the exceedance curves are “stepped” compared to the full dataset because of the narrower range of operating and hydrologic conditions that occurs in a single month and year to year variability.

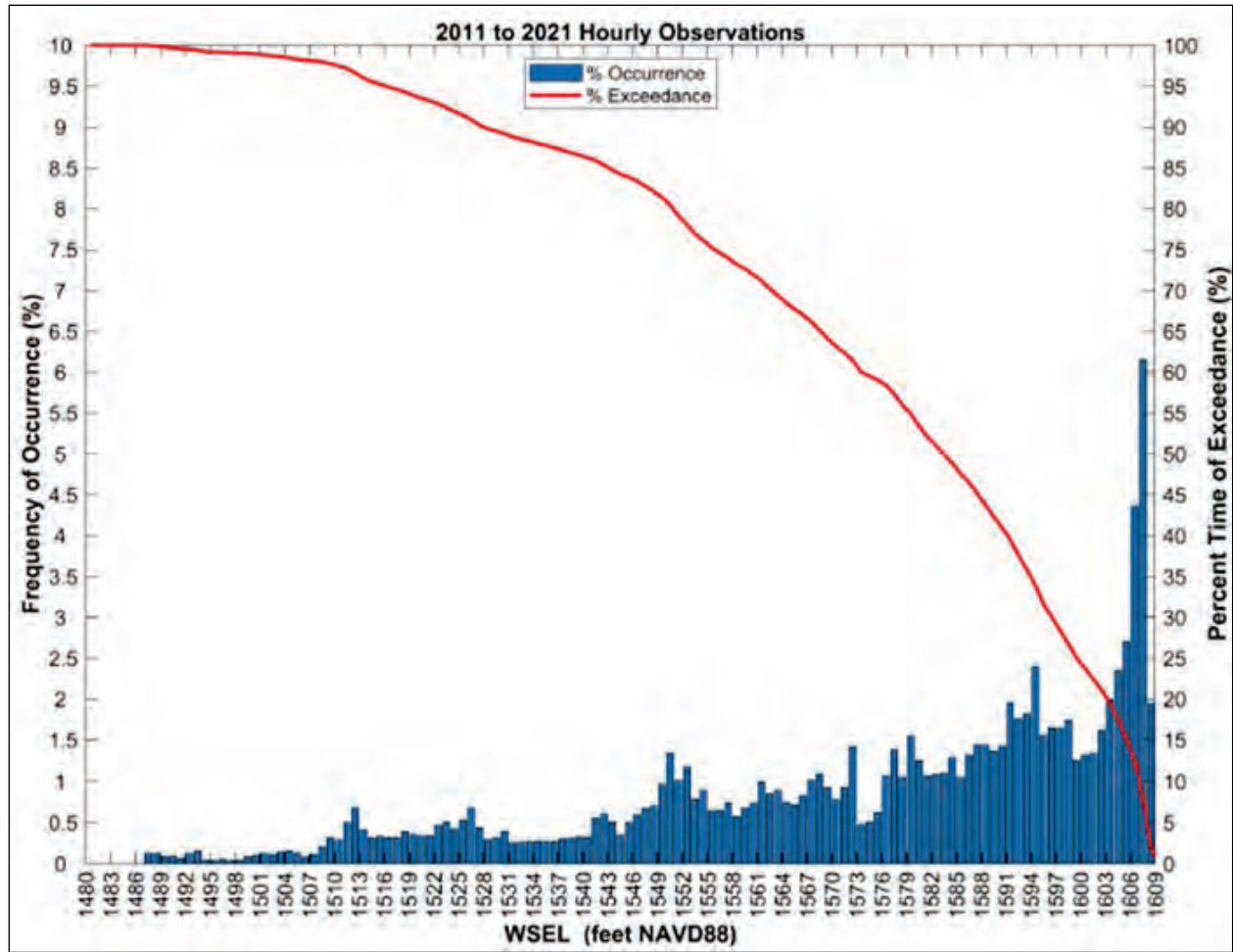


Figure 5.2-11. Frequency of occurrence and exceedance for hourly WSEL records at Ross Lake (2011 to 2021).

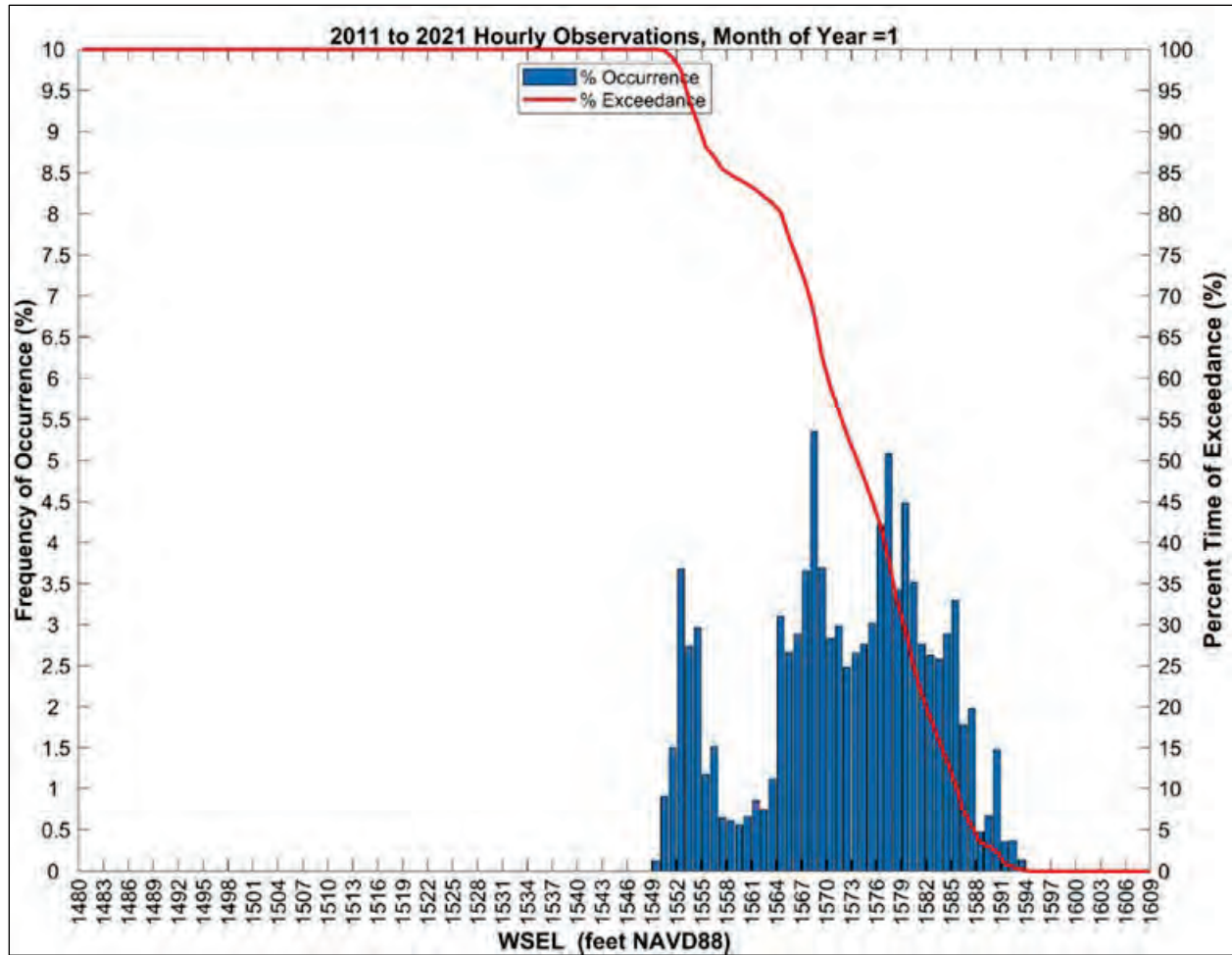
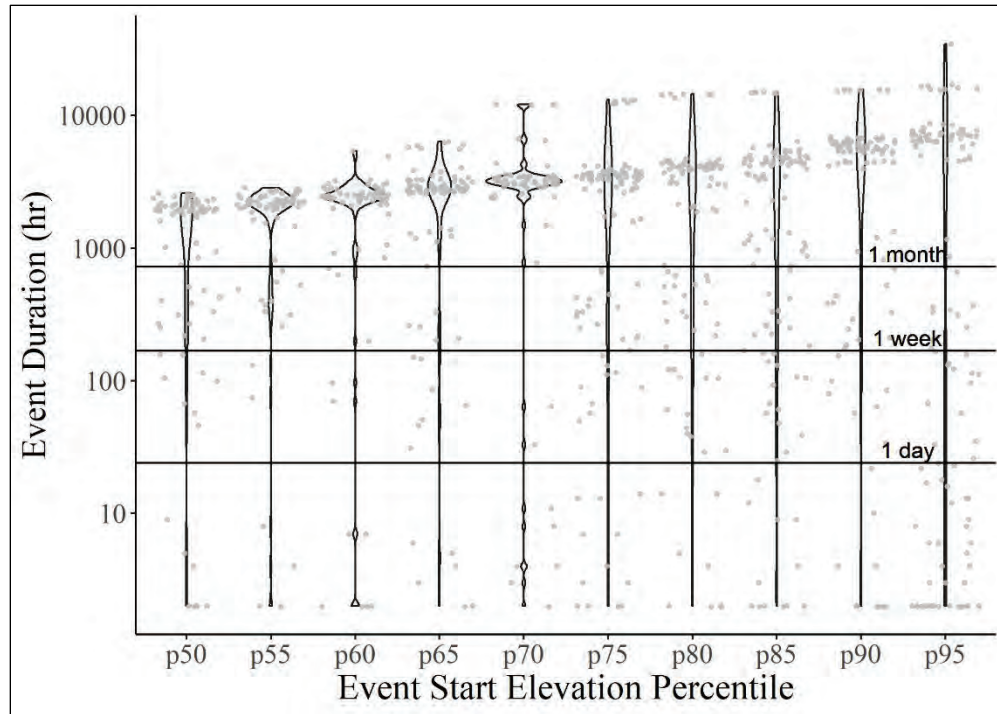


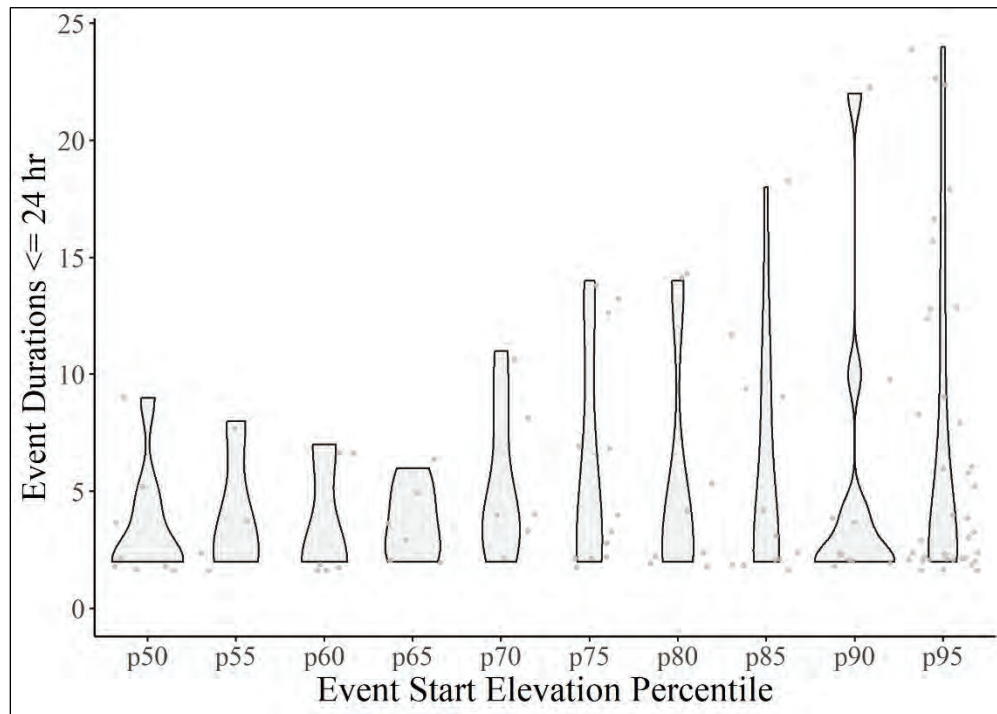
Figure 5.2-12. Frequency of occurrence and exceedance for hourly WSE records during the month of January at Ross Lake (2011 to 2021).

Overall, most fluctuations within Ross Lake occurred around annual WSE maxima and minima, with one large drawdown each year. The majority of drawdown events within Ross Lake lasted for more than a month across elevations (Figure 5.2-13). Most fluctuations (or minor drawdown events) shorter than one day, lasted for less than five hours (Figure 5.2-14).



Note: Event thresholds were grouped by normal WSE percentiles.

Figure 5.2-13. Ross Lake drawdown event duration for all drawdown events (2011 to 2021).



Note: Event thresholds were grouped by normal WSE percentiles.

Figure 5.2-14. Ross Lake drawdown event duration for drawdown events less than or equal to 24 hours duration (2011 to 2021).

5.2.2.2 Diablo and Gorge Lakes

Between 2011 and 2021, Diablo Lake WSE ranged between 1,199.4 and 1,211.5 feet NAVD 88 (1,193.0 and 1,205.1 feet CoSD, Table 5.2-6 and Figure 5.2-15). During this period, Gorge Lake WSE ranged between 821.7 and 881.4 feet NAVD 88 (815.2 and 874.9 feet CoSD, Table 5.2-7 and Figure 5.2-16). The typical WSE operating range for Diablo Lake is between 1,206 and 1,211 feet NAVD 88 (1,199.6 and 1,204.6 feet CoSD) with drawdowns to about 1,200 feet NAVD 88 (1,193.6 feet CoSD) for maintenance. The typical WSE operating range for Gorge Lake is between 876 and 880 feet NAVD 88 (869.5 and 873.5 feet CoSD) with drawdowns of more than 50 feet for maintenance.

Gorge and Diablo lakes commonly fluctuate between 3 to 5 feet within the normal operating range on a daily basis. However, daily changes in water levels of up to 7 feet were measured at Diablo Lake (Figure 5.2-15) and 29 feet at Gorge Lake (Figure 5.2-16) between 2011 and 2021. Drawdowns of Diablo and Gorge lakes were analyzed to characterize the water level fluctuations during normal operations by week, month, and season as an input to estimate the frequency at which trapping pools form and stranding areas become exposed.

Table 5.2-6. Diablo Lake WSE statistics (2011 to 2021).

Statistic	WSE (feet NAVD 88)
Minimum	1,199.4
Maximum	1,211.5
Median	1,207.5
Mean	1,207.4
Range	12.1

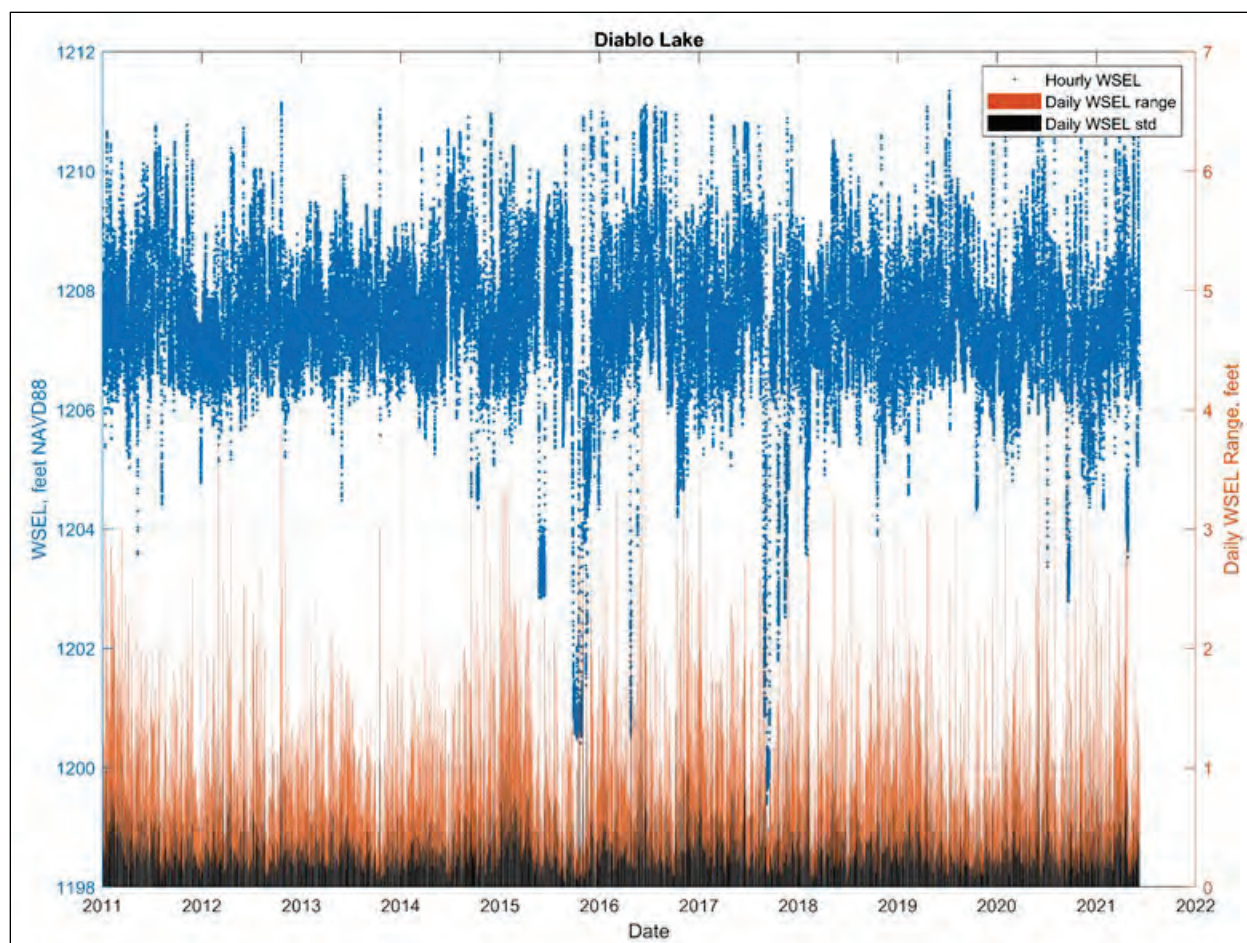


Figure 5.2-15. Diablo Lake WSE time series (2011 to 2021).

Table 5.2-7. Gorge Lake WSE statistics (2011 to 2021).

Statistic	WSE (feet NAVD 88)
Minimum	821.7
Maximum	881.4
Median	877.6
Mean	875.9
Range	59.8

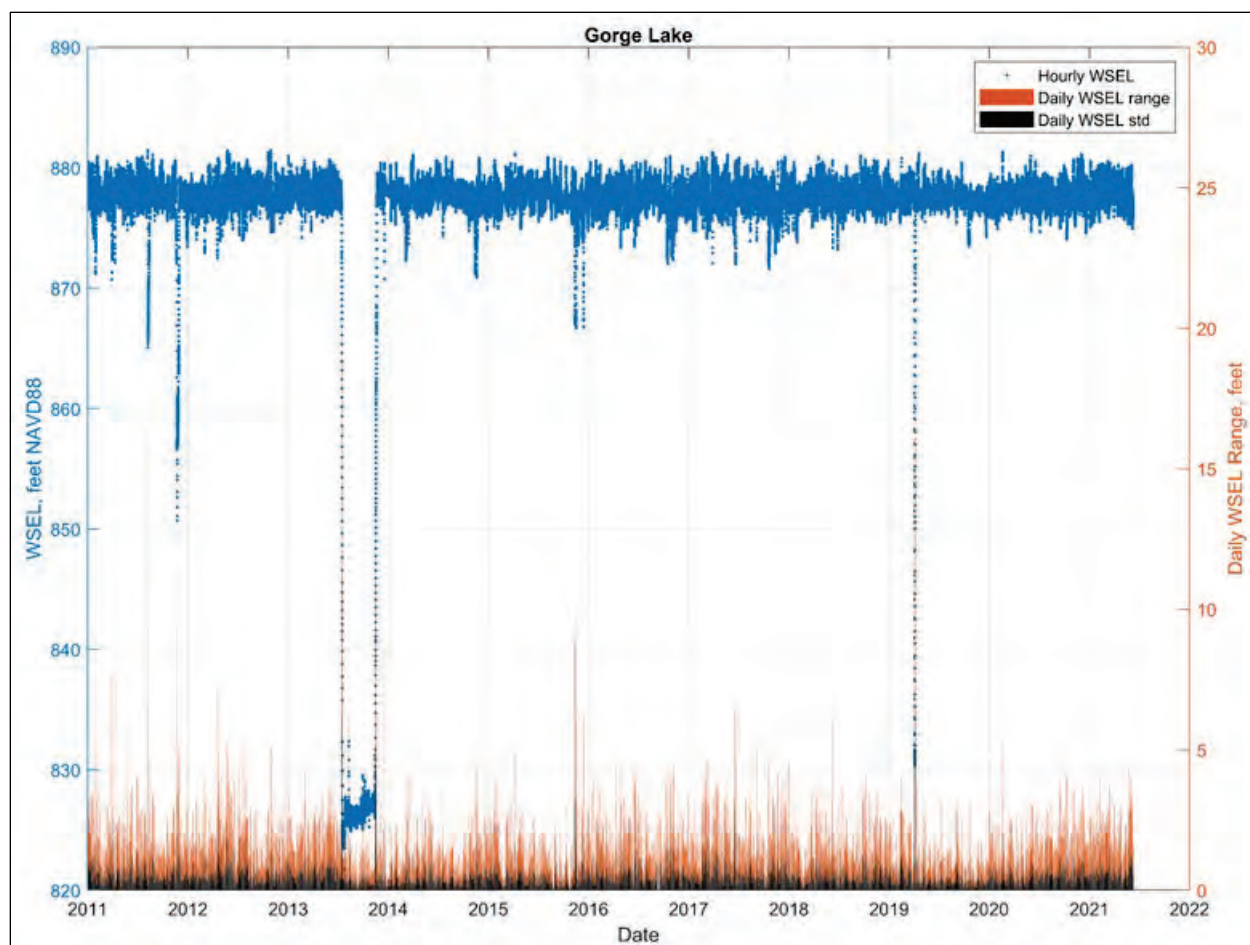


Figure 5.2-16. Gorge Lake WSE time series (2011 to 2021).

The statistics by month for Diablo Lake (Table 5.2-8) over the period of record indicate there is minimal variation in monthly mean water level at Diablo Lake throughout the year, with a variation in the monthly mean of 2 feet (standard deviation = 0.4 feet). More seasonality is evident at Gorge Lake (Table 5.2-9) where the minimum mean water level occurs from August to September (872 feet NAVD 88 [865.5 feet CoSD]) and increases to an average of 877 feet NAVD 88 (870.5 feet CoSD) from January through May.

Table 5.2-8. Diablo Lake WSE statistics by month of year based on data from January 1, 2011 thru June 9, 2021.

Statistic	Water Surface Elevation (feet NAVD 88)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Minimum	1,203.6	1,203.6	1,205.1	1,200.5	1,202.9	1,202.9	1,203.4	1,200.9	1,199.4	1,200.4	1,201.4	1,204.3
Maximum	1,211.0	1,211.1	1,210.9	1,211.1	1,211.0	1,211.5	1,211.3	1,211.0	1,210.9	1,211.1	1,211.0	1,211.0
Median	1,207.5	1,207.3	1,207.5	1,207.4	1,207.7	1,208.0	1,207.9	1,207.9	1,207.5	1,207.2	1,207.1	1,207.2
Mean	1,207.5	1,207.3	1,207.5	1,207.5	1,207.7	1,207.9	1,208.0	1,207.9	1,207.1	1,206.7	1,207.0	1,207.2
Variance	0.8	0.7	0.6	1.3	1.4	2.1	0.9	1.6	3.8	4.4	1.6	0.7
Range	7.4	7.5	5.8	10.5	8.2	8.6	8.0	10.1	11.5	10.7	9.6	6.7

Table 5.2-9. Gorge Lake WSE statistics by month of year based on data from January 1, 2011 thru June 9, 2021.

Statistic	Water Surface Elevation (feet NAVD 88)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Minimum	871.2	874.0	870.7	830.3	874.3	872.0	821.7	824.9	825.1	825.3	826.0	866.8
Maximum	880.9	881.3	881.3	881.2	881.4	881.1	880.9	881.4	881.0	881.4	880.8	881.1
Median	877.7	877.6	877.7	877.7	877.8	877.8	877.7	877.8	877.7	877.3	877.2	877.6
Mean	877.6	877.7	877.7	877.4	877.9	877.8	875.2	872.7	872.6	872.3	874.1	877.5
Variance	1.0	0.7	1.1	14.0	0.9	1.1	127.7	242.3	242.9	227.9	126.1	1.2
Range	9.8	7.2	10.6	50.8	7.1	9.1	59.2	56.5	55.9	56.1	54.8	14.3

The frequency of occurrence and percent exceedance curves for the full dataset at Diablo Lake and Gorge Lake from 2011 to 2021 are plotted in Figure 5.2-17 and Figure 5.2-18, respectively. The most frequently occurring water levels at Diablo Lake are between 1,207 and 1,208 feet NAVD 88 (1,200.6 and 1201.6 feet CoSD). The most frequently occurring water levels at Gorge Lake are between 876 and 877 feet NAVD 88 (869.5 and 870.5 feet CoSD). A big step in the exceedance curve is the result of a large drawdown event that temporarily lowered the water level to 821 feet NAVD 88 (814.5 feet CoSD) in 2013.

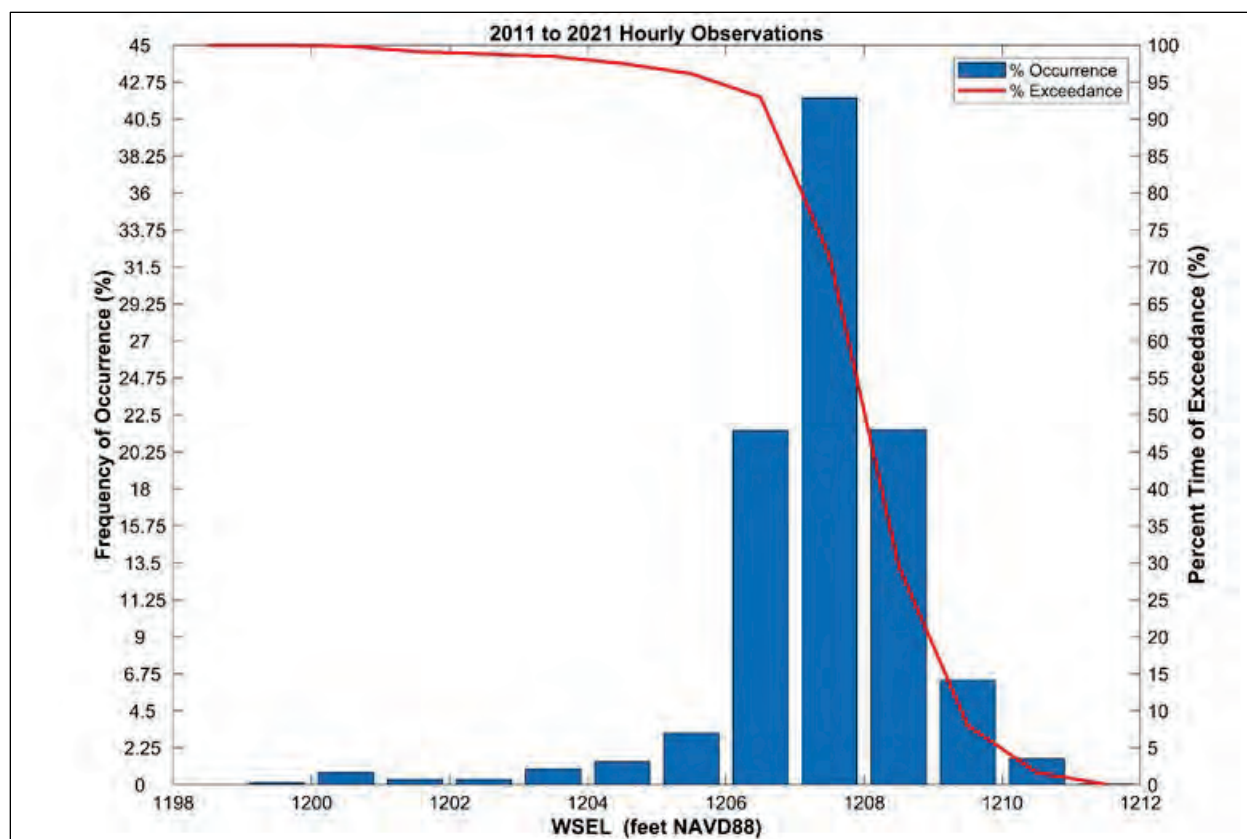


Figure 5.2-17. Frequency of occurrence and exceedance for hourly WSEL records at Diablo Lake (2011 to 2021).

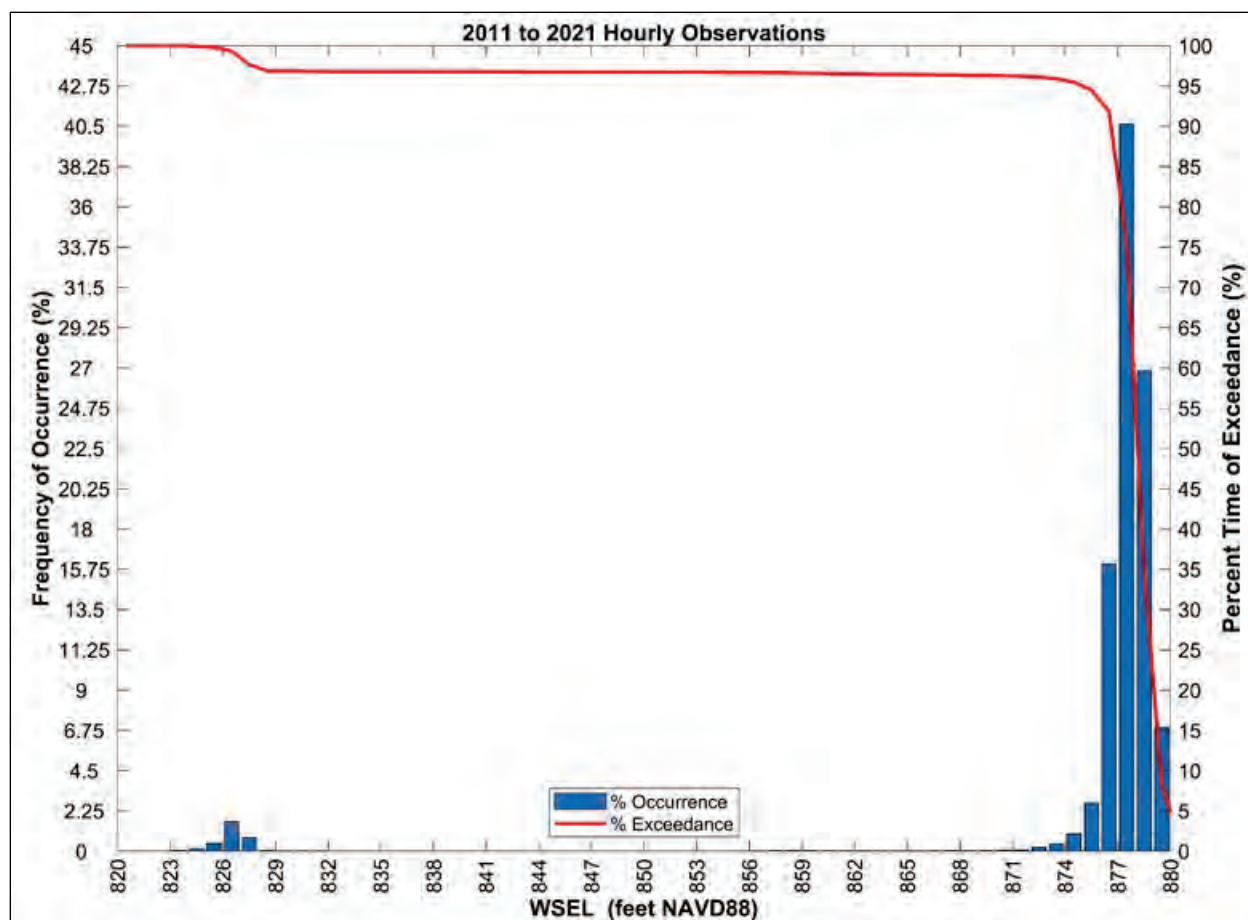


Figure 5.2-18. Frequency of occurrence and exceedance for hourly WSE records at Gorge Lake (2011 to 2021).

Several thousand drawdown events were identified at both Diablo and Gorge lakes (Tables 5.2-10 and 5.2-11) between 2011 and 2021. Below, these events are categorized by rim elevation and month of the year. The mean and median duration of the events are provided for each rim elevation. Figures 5.2-19 and 5.2-20 illustrate the identified drawdown events for a given rim elevation (1,206 and 876 feet, respectively) from the time series. The number of events is highest near the mean of the operating range for a given lake because of the increased frequency of short-term fluctuations around the mean water level. Drawdowns around the mean water level typically last from six to nine hours at both lakes.

Table 5.2-10. Diablo Lake WSE statistics by month of year based on data from January 1, 2011 thru June 9, 2021.

Rim El.	No. of Events	Mean Duration (hours)	Median Duration (hours)	Number of Events by Month of Year											
				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1,204	33	488.4	53.0	2	2	0	5	4	0	1	1	4	6	8	0
1,205	83	70.2	10.0	4	7	0	3	5	0	1	3	5	14	31	10
1,206	172	25.8	7.0	28	40	29	20	20	8	7	7	9	23	35	36
1,207	1,574	18.0	9.0	183	185	184	161	117	69	90	73	90	98	148	176
1,208	1,279	51.8	19.0	142	106	153	129	123	107	104	96	84	81	65	89
1,209	272	178.2	57.0	35	22	34	47	50	77	54	65	33	26	19	14
1,210	111	812.0	378.0	8	5	5	8	15	21	17	10	3	3	12	4
1,211	9	10,163.4	7,876.0	1	0	0	1	0	4	2	0	0	1	0	0

Table 5.2-11. Gorge Lake WSE statistics by month of year based on data from January 1, 2011 thru June 9, 2021.

Rim El.	No. of Events	Mean Duration (hours)	Median Duration (hours)	Number of Events by Month of Year											
				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
870	7	488.4	53.0	0	0	0	1	0	0	1	1	0	0	3	1
871	10	348.2	18.0	0	0	1	1	0	0	1	1	0	0	4	2
872	14	254.6	19.0	1	0	1	1	0	1	1	1	0	1	5	2
873	34	111.5	9.0	2	0	6	4	0	1	1	2	0	7	9	2
874	58	72.4	7.5	3	0	7	5	0	6	2	2	1	12	16	4
875	129	40.0	7.0	15	6	13	9	3	14	8	4	3	13	25	16
876	422	18.8	6.0	49	34	36	35	35	40	26	15	20	33	50	49
877	1,779	13.6	8.0	182	158	164	158	180	157	132	91	115	128	138	176
878	2,129	29.1	15.0	191	178	210	220	221	188	168	159	172	139	108	175
879	871	97.6	37.0	71	67	92	98	124	94	66	73	44	38	49	55
880	197	459.3	180.0	20	14	20	22	20	17	16	14	7	9	20	18
881	12	7,622.3	6071.0	1	1	2	2	2	0	0	1	0	2	0	1

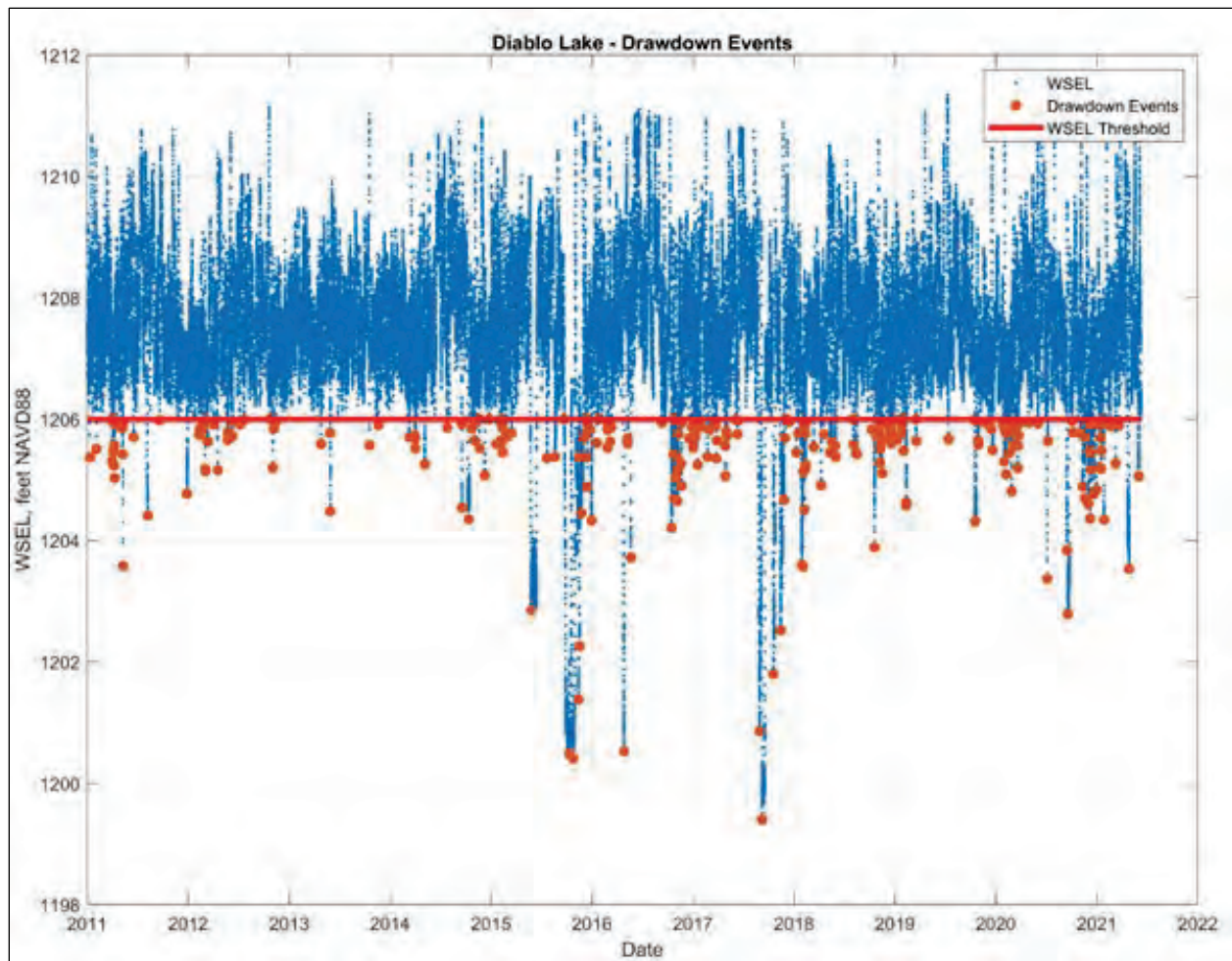


Figure 5.2-19. Time series of drawdown events at Diablo Lake for a rim elevation of 1,206 feet NAVD 88 (2011 to 2021).

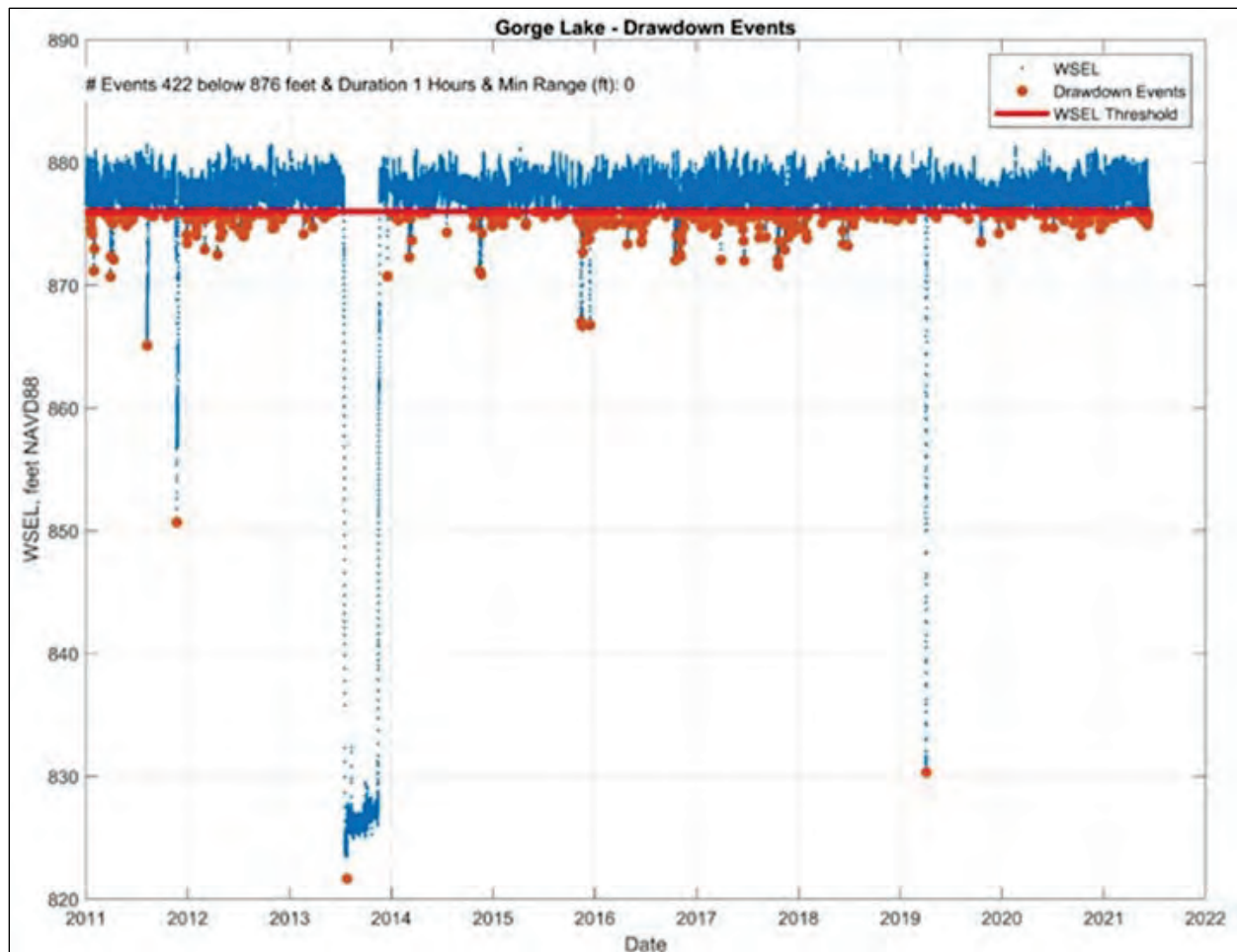


Figure 5.2-20. Time series of drawdown events at Gorge Lake for a rim elevation of 876 feet NAVD 88 (2011 to 2021).

Most drawdown events beginning at or below 1,208 feet NAVD 88 (1,201.6 feet CoSD) in Diablo Lake lasted for less than a day, while those above 1,208 feet NAVD 88 lasted for more than a week (Figure 5.2-21). This was primarily due to the WSE not reaching maximum WSE often and, therefore, infrequently drawing down from the normal maximum WSE. The majority of drawdown events, particularly those lasting less than 24 hours, were concentrated between 1,207-1,209 feet NAVD 88 (1,200.6-1,202.6 feet CoSD; Figure 5.2-22).

The majority of drawdown events starting from 878 feet NAVD 88 (871.5 feet CoSD) in Gorge Lake lasted for less than 3 days, and drawdowns from 877 feet NAVD 88 (870.5 feet CoSD) or below mostly lasted less than 1 day (Figure 5.2-23). The majority of drawdown events lasting less than 24 hours occurred between 876 through 879 feet NAVD 88 (869.5-872.5 feet CoSD; Figure 5.2-24).

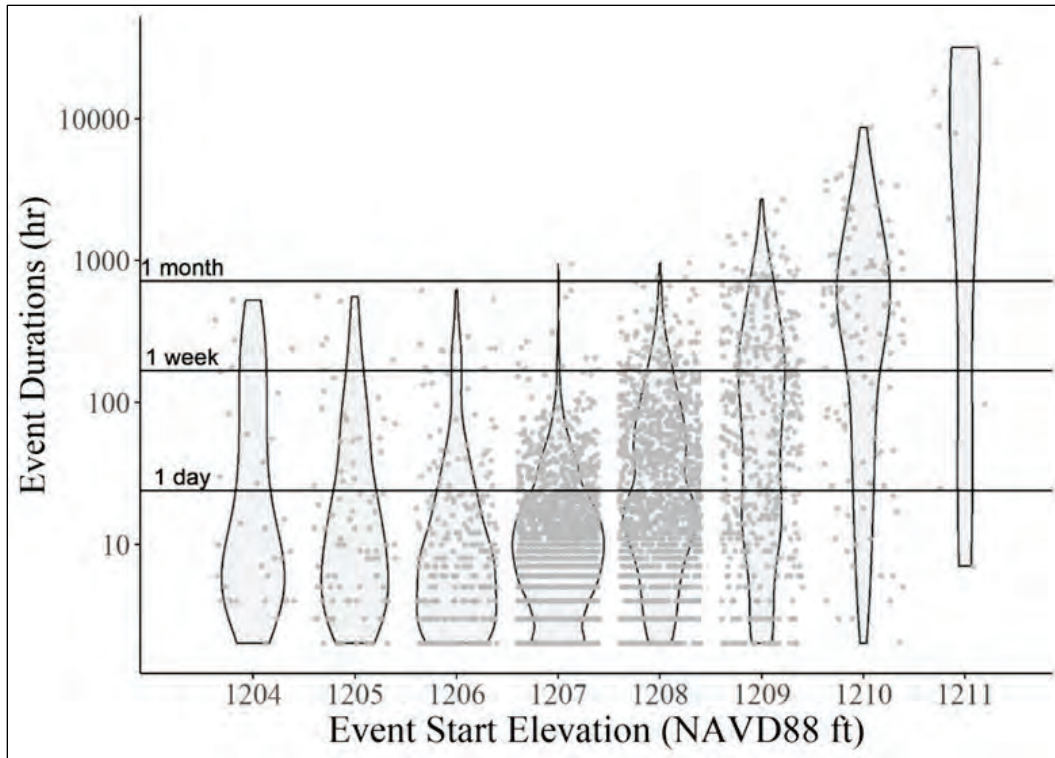


Figure 5.2-21. Diablo Lake drawdown event duration for all drawdown events (2011 to 2021).

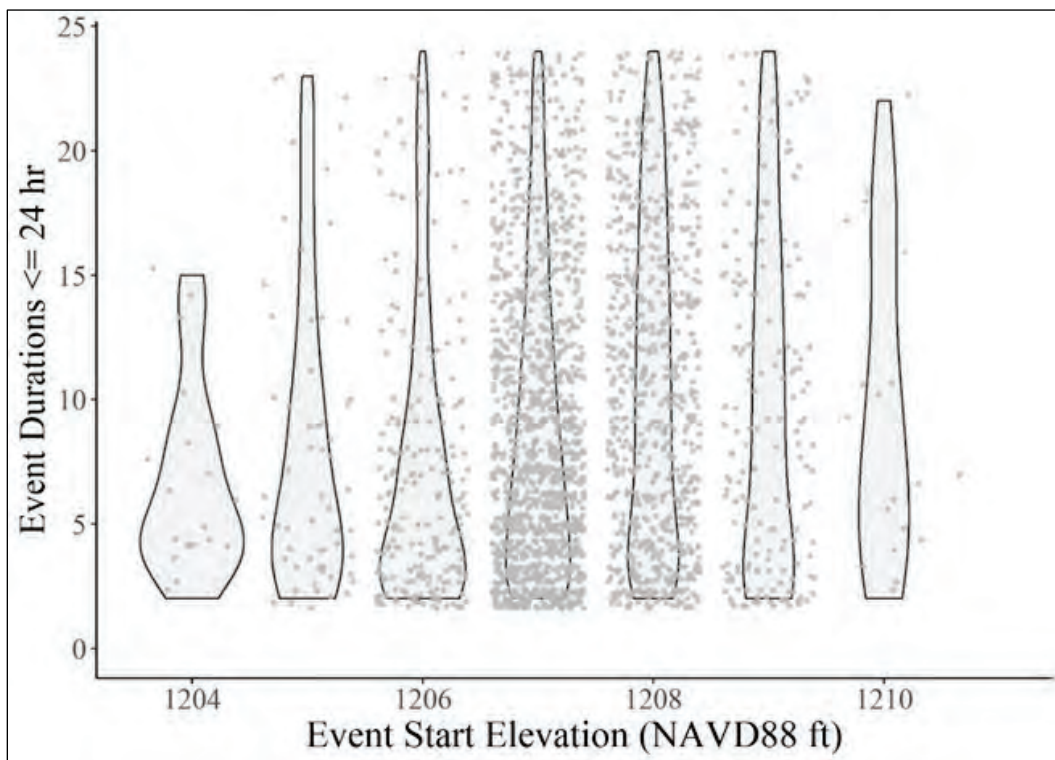


Figure 5.2-22. Diablo Lake drawdown event duration for drawdown events less than or equal to 24 hours duration (2011 to 2021).

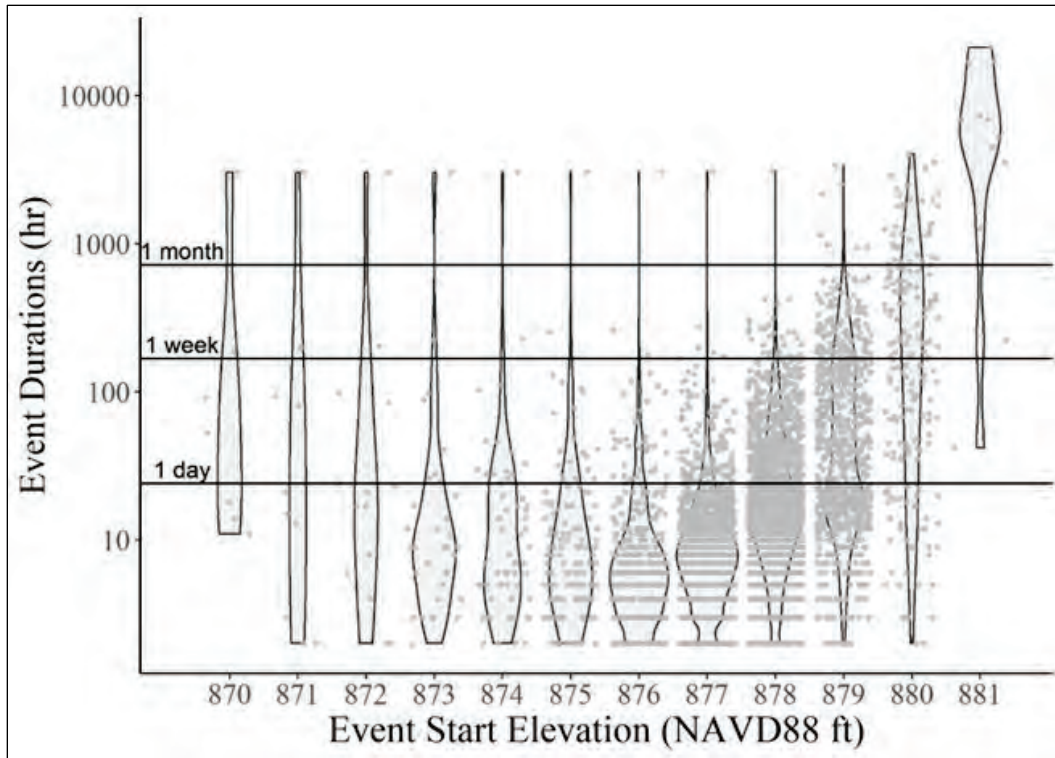


Figure 5.2-23. Gorge Lake drawdown event duration for all drawdown events (2011 to 2021).

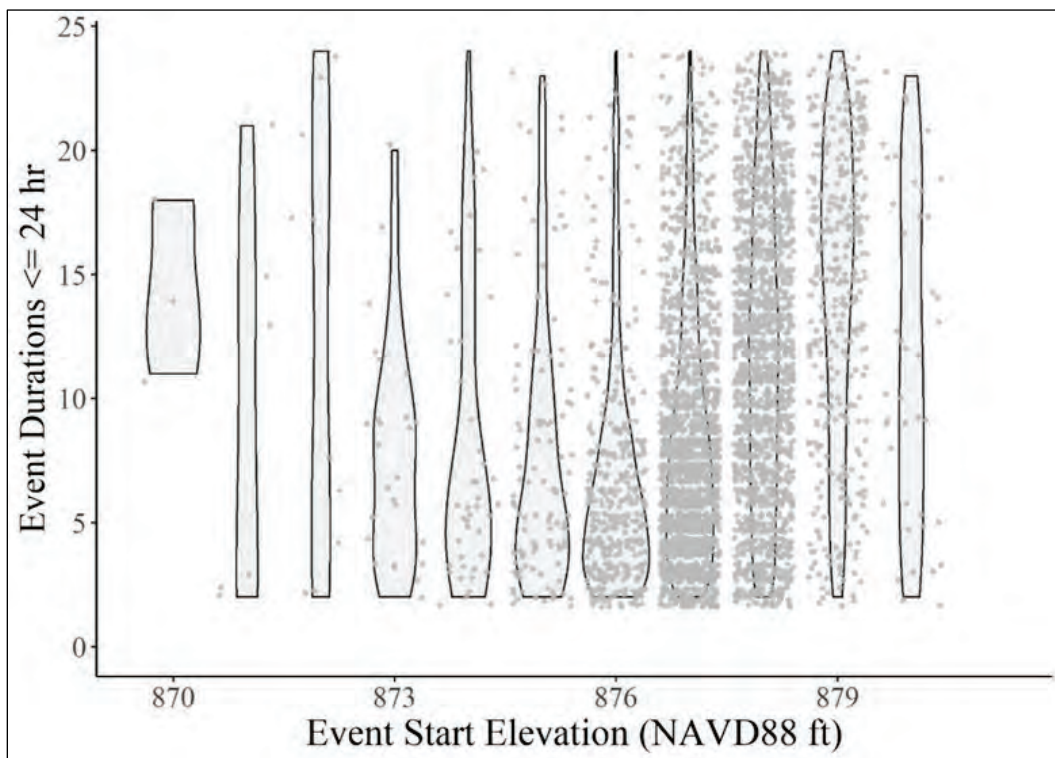


Figure 5.2-24. Gorge Lake drawdown event duration for drawdown events less than or equal to 24 hours duration (2011 to 2021).

5.2.3 Integration of Reservoir Drawdown and GIS Analyses

5.2.3.1 Ross Lake

In Ross Lake, the majority of potential stranding risk areas exposed during drawdown events lasting less than one day occurred during the summer months, when the reservoir was close to annual maximum WSE. The majority of stranding risk area exposures occurred during the fall (September-November) in the upper 15 percent of the reservoir. The highest amount of potential stranding risk areas exposed when the reservoir was between 55-85 percent capacity occurred during January and into February (Figure 5.2-25).

Most exposures of potential trapping risk areas occurred during the late summer and into the fall in the upper 10 percent of reservoir WSE (Figure 5.2-26). In the winter, most of the sink exposure was concentrated around 60 percent WSE, largely due to a relatively higher concentration of potential sinks at that elevation percentile compared to the more evenly distributed low slope areas throughout the middle percentiles of the reservoir.

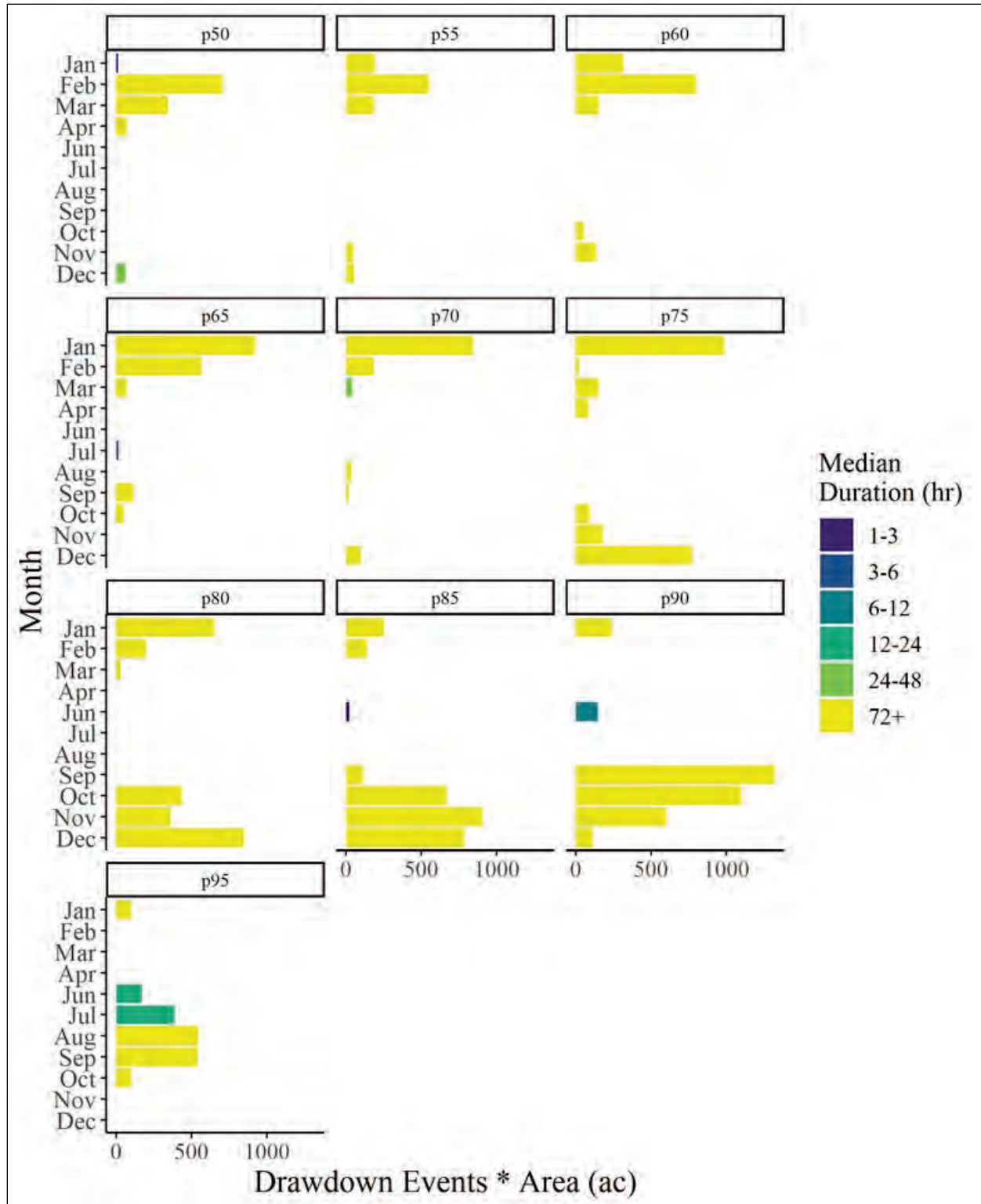


Figure 5.2-25. Monthly Ross Lake drawdown event counts (2011 to 2021) multiplied by low slope area in the upper 50 percent water surface elevation percentile.

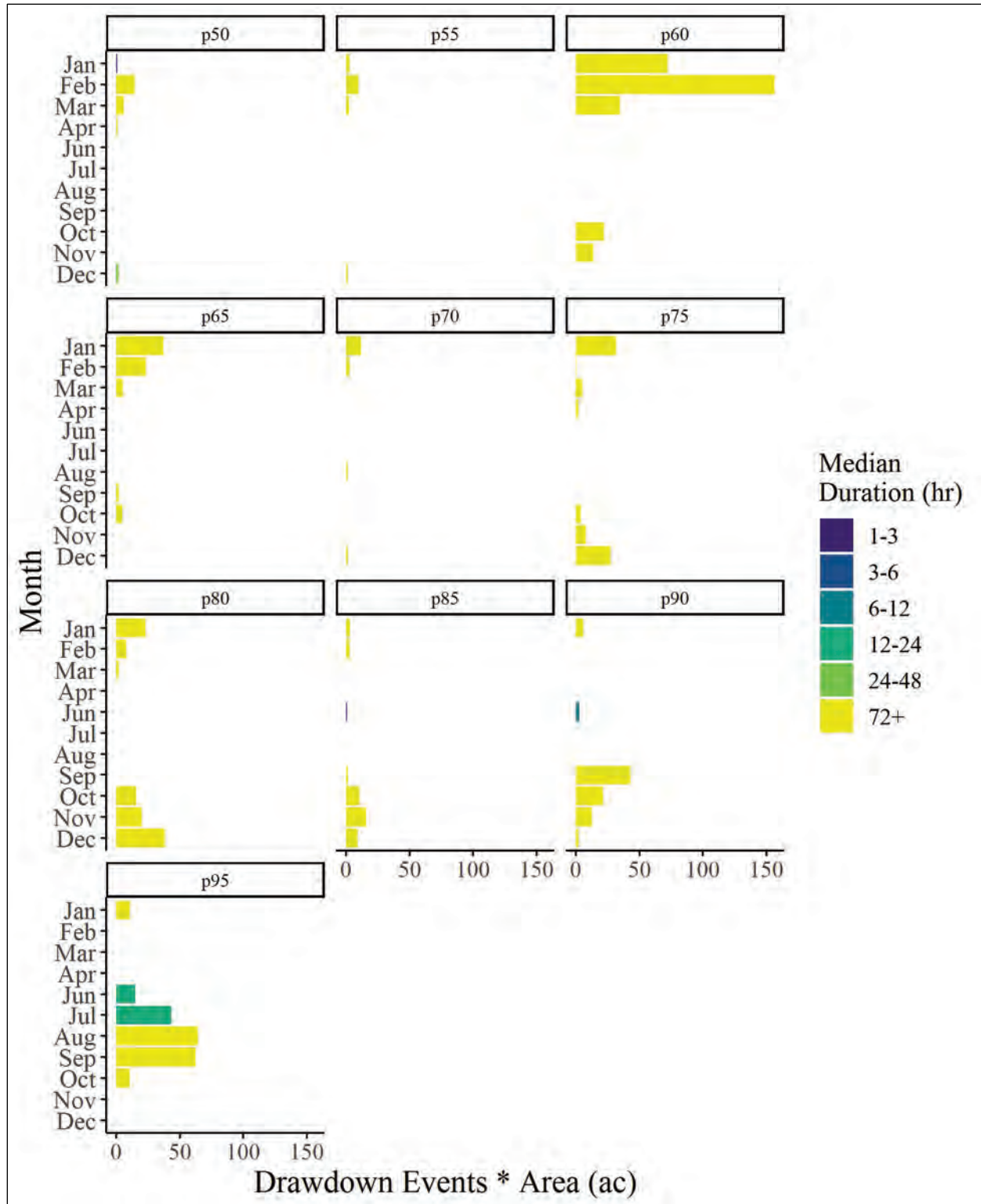


Figure 5.2-26. Monthly Ross Lake drawdown event counts (2011 to 2021) multiplied by sink area in the upper 50 percent water surface elevation percentile.

5.2.3.2 Diablo and Gorge Lakes

In Diablo Lake, the highest potential stranding risk was at 1,207-1,208 feet NAVD 88 (1,200.6-1,201.6 feet CoSD) (Figure 5.2-27) due to a combination of the relatively high proportion of low slope area at those elevations and their high drawdown frequency. Drawdown events from 1,208 feet NAVD 88 (1,201.6 feet CoSD) were slightly longer, as drawdowns passing both elevations took longer to return to the higher elevation band. Potential trapping risk was concentrated at 1,207 feet NAVD 88 (1,200.6 feet CoSD) due to higher potential sink area at that elevation band (Figure 5.2-28).

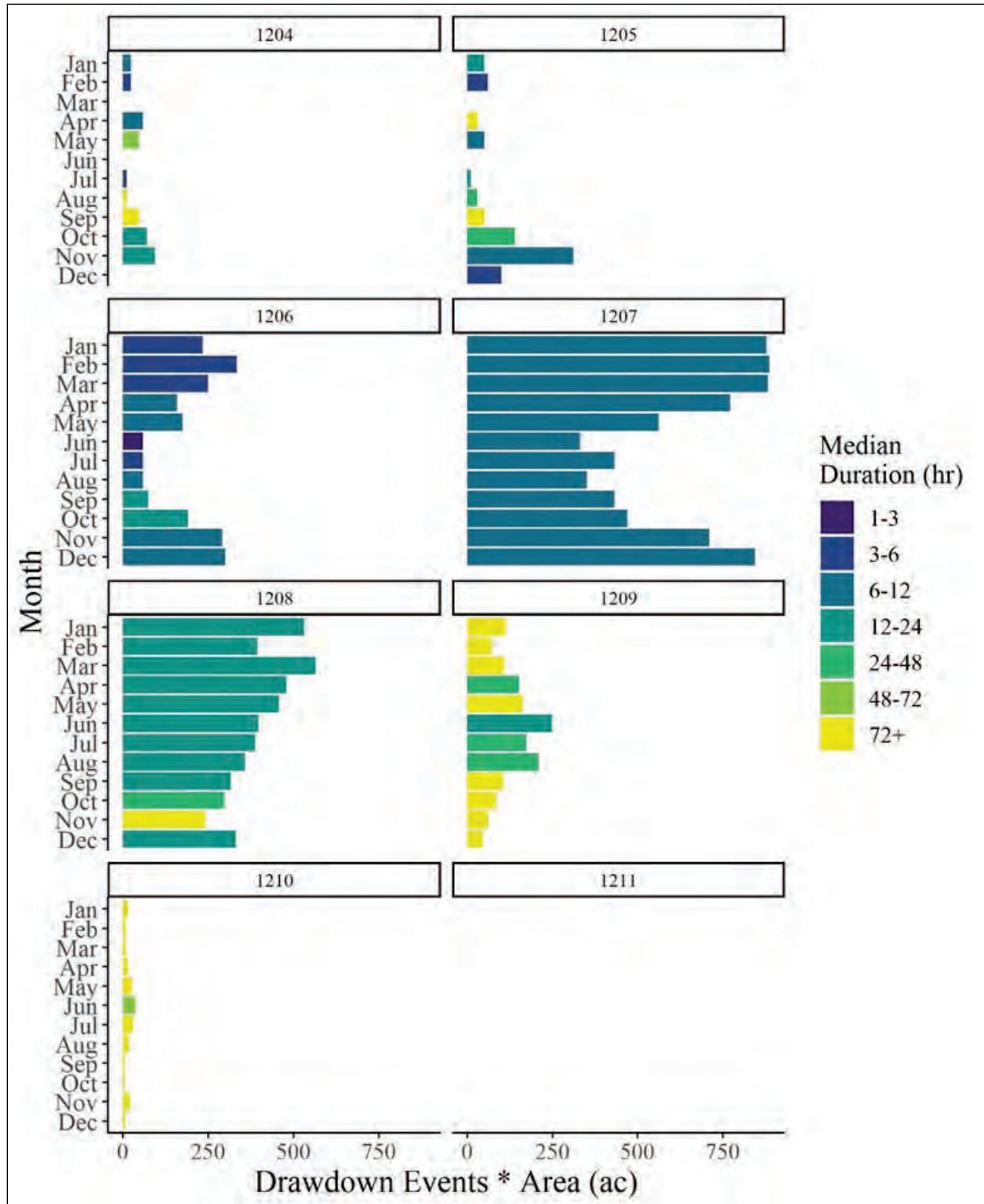


Figure 5.2-27. Monthly Diablo Lake drawdown event counts (2011 to 2021) multiplied by low slope area within the varial zone.

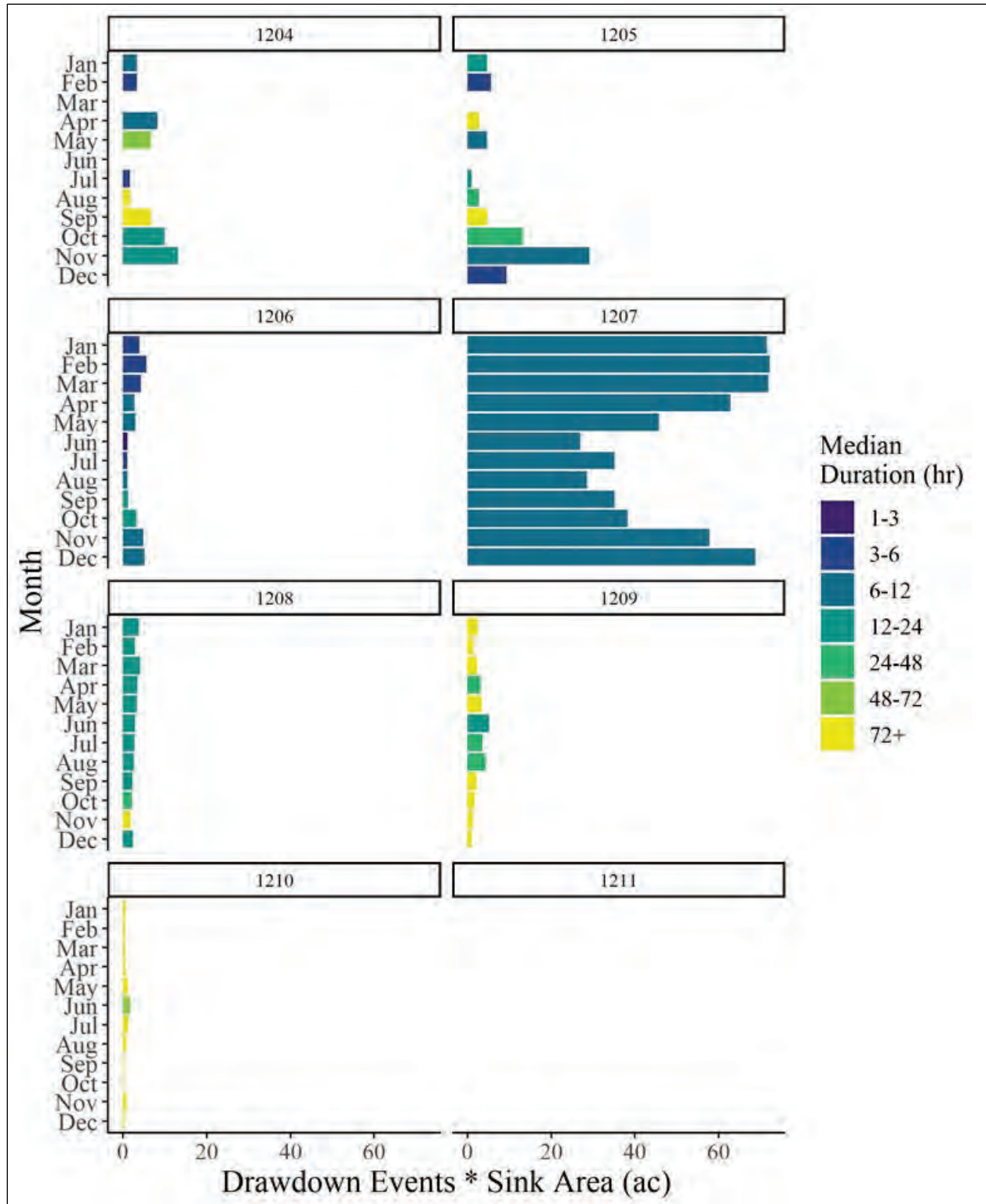


Figure 5.2-28. Monthly Diablo Lake drawdown event counts (2011 to 2021) multiplied by sink area within the varial zone.

In Gorge Lake, the highest areas of potential stranding and trapping risks were concentrated in the upper 75 percent of elevation bands due to both the terrain and the drawdown event frequency at those elevation bands (Figures 5.2-29 and 5.2-30). The highest amount of potential stranding risk was concentrated at 877-878 feet NAVD 88 (870.5-871.5 feet CoSD). The highest trapping risk was between 875-876 feet NAVD 88 (868.5-869.5 feet CoSD). The latter is primarily driven by the high sink area exposed between 875-876 feet NAVD 88 (868.5-869.5 feet CoSD). Data gaps between approximately 868-876 feet NAVD 88 (861.5-869.5 feet CoSD) in the lower half of the reservoir, particularly at the mouth of Gorge Creek and other tributaries, may be artificially lowering both the stranding and trapping risks at those elevations, particularly across the frequently dewatered 874-876 feet NAVD 88 (867.5-869.5 feet CoSD).

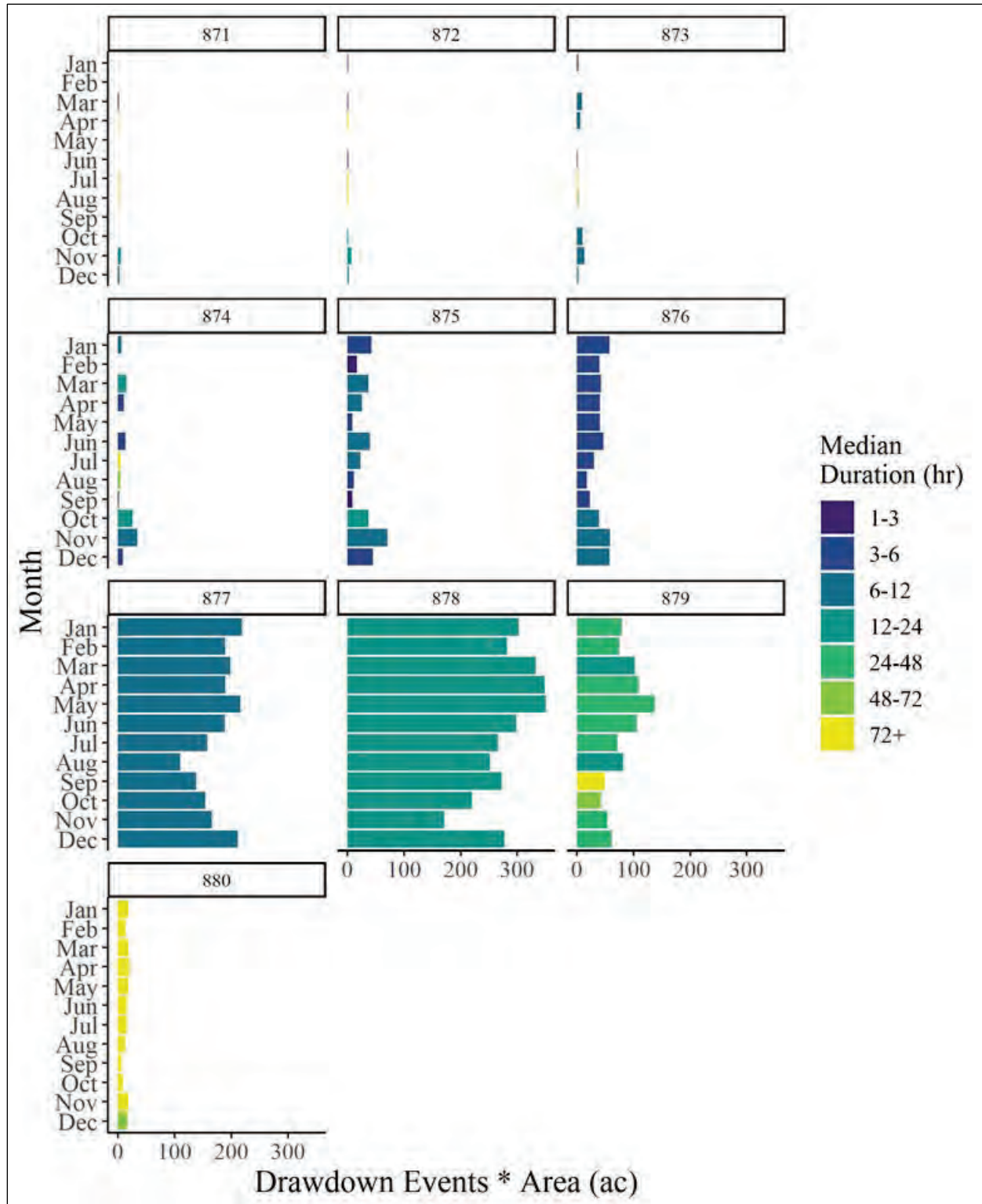


Figure 5.2-29. Monthly Gorge Lake drawdown event counts (2011 to 2021) multiplied by low slope area across frequently dewatered elevation bands.

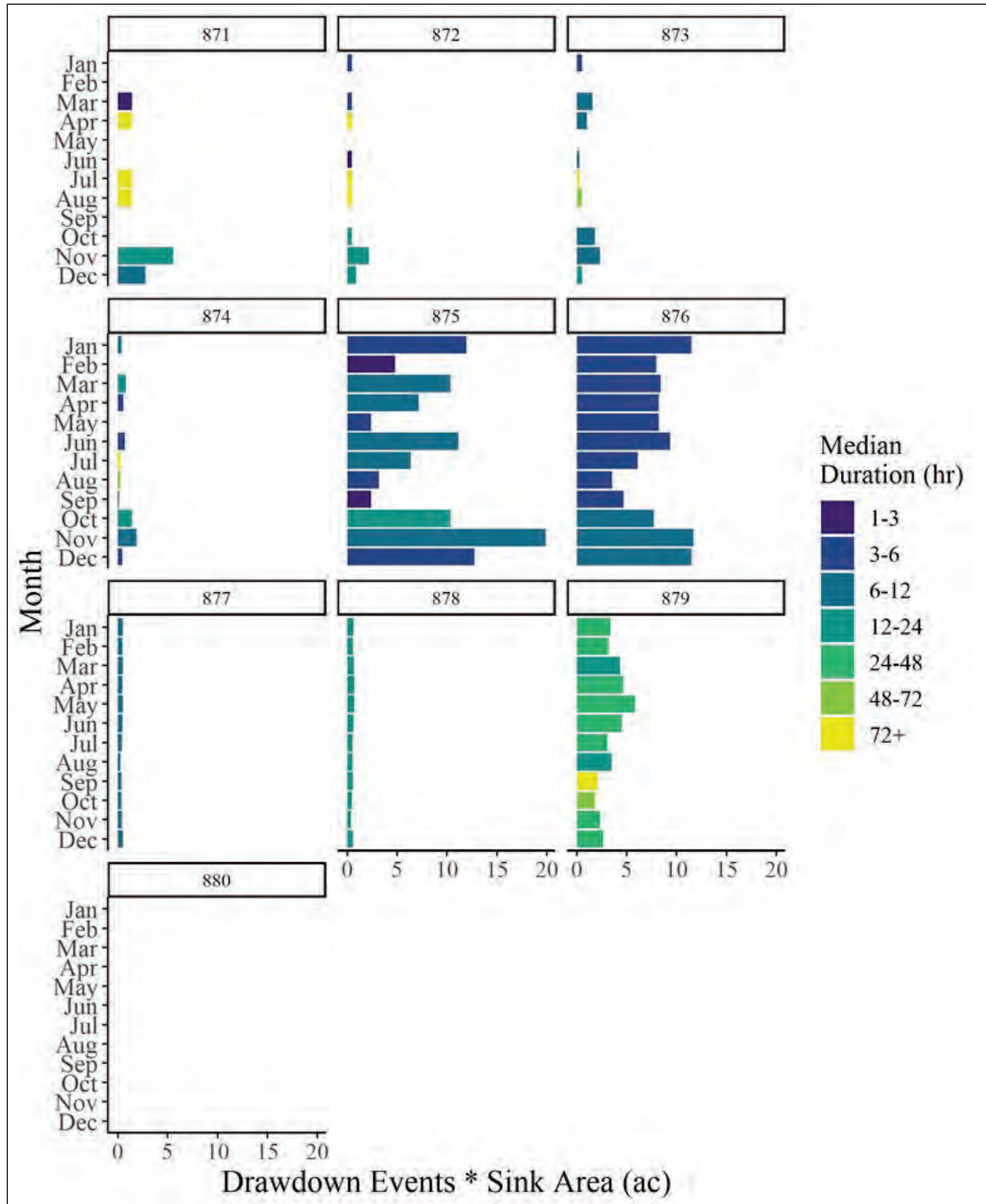


Figure 5.2-30. Monthly Gorge Lake drawdown event counts (2011 to 2021) multiplied by sink area across frequently dewatered elevation bands.

5.2.4 Native Species Life Stage and Periodicity Analysis

5.2.4.1 Background

Native fish species found within Ross, Diablo, and Gorge lakes are Bull Trout, Dolly Varden, and Rainbow Trout. These species were the focus of this periodicity analysis and are discussed in detail below.

Introduced species within Ross Lake include Brook Trout (*Salvelinus fontinalis*) and Redside Shiner (*Richardsonius balteatus*), plus Cutthroat Trout (*Oncorhynchus clarkii*) (Derenne 2014). Brook Trout from Pennsylvania were stocked in the sub-alpine lakes found around Ross Lake in the early 1900s and have been noted in Hozomeen and Big Beaver creeks. Current research associated with the FA-06 Reservoir Native Fish Genetics Study identified Brook Trout in Ross Lake tributaries Silver, Hozomeen, and Three Fools creeks and Diablo Lake tributary Thunder Creek. Dolly Varden x Brook Trout hybrids were identified in Silver and Pierce creeks in Ross Lake, and Thunder and Colonial creeks in Diablo and Gorge lakes. Welch (2012) noted that Redside Shiner were introduced to Ross Lake as baitfish around the year 2000 and are prevalent (hundreds per cubic meter) in some reservoir areas. Westslope Cutthroat Trout and Coastal Cutthroat Trout were stocked in areas upstream of Gorge Dam in the early 1900s (City Light 2020).

Studies on species use and behavior specific to each of the three reservoirs are limited except for reservoir-specific spawning locations. Most information is described as the “Upper Skagit” or “Project Area.” Because of this, all three are grouped in Figure 5.2-31, and location-specific behaviors are described later in this section.

Species	Lifestage	Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Native Char	Adults	Lake - Shallow water												
	Adults	Lake - Deep water												
	Adults	Streams												
	Adults	Stream inlets												
	Spawning	Streams												
	Fry	Streams												
	Juveniles	Streams												
	Juveniles	Lake - Shallow water												
	Juveniles	Lake - Deep water												
Rainbow Trout	Adults	Lake - Shallow water												
	Adults	Lake - Deep water												
	Adults	Streams												
	Adults	Stream inlets												
	Spawning	Streams												
	Spawning	Stream inlets												
	Fry	Streams												
	Fry	Stream inlets												
	Juveniles	Streams												
	Juveniles	Stream inlets												
	Juveniles	Lake - Shallow water												
	Juveniles	Lake - Deep water												
			Present				Less Present				Not Present			

Note: Native Char includes Bull Trout and Dolly Varden, as most population studies did not differentiate between the two species.

Figure 5.2-31. Monthly use by native char and Rainbow Trout within Ross, Diablo, and Gorge lakes.

5.2.4.2 Native Char

Due to the past limited knowledge, similar appearance, and overlapping geographic distributions of Bull Trout and Dolly Varden upstream of Gorge Dam, most fish population studies conducted do not differentiate the two species. Because of this, many studies refer to them as “char” or “native char” (City Light 2011; USFWS 2004). The term native char (from here on known as “char”) is displayed in Figure 5.2-31, as most available information groups the two species together. Any species-specific differences are discussed below.

Use of the Lake Environment

Char have been documented in Ross, Diablo, and Gorge lakes. They demonstrate adfluvial life histories in which they spawn and rear in tributaries and migrate to the reservoirs to forage during their adult lives (Downen 2004; City Light 2011; USFWS 2004).

Cold waters are preferred by char: they tend to avoid temperatures above 15 degrees Celsius (°C), and this influences their distribution within the reservoirs (USFWS 2004). Gillnet sampling of all three reservoirs produced higher catch numbers near coldwater sources: Ross Lake – mouth of Big Beaver Creek; Diablo Lake – the powerhouse and Thunder Creek; and Gorge Lake – the powerhouse and Stetattle Creek (Downen 2014). At each reservoir, char ranging in ages 1-5 were captured, with age 6 also encountered in Diablo and Ross.

Within Ross Lake, adult char have been shown to conduct daily vertical migrations between shallow and deep (up to 192 feet) waters during the peak of thermal stratification in July and August (Eckmann et al. 2016). While in these shallow areas, they fed almost exclusively on the introduced Redside Shiner. NPS (2018) expects the same pattern to occur within Diablo Lake as it also thermally stratifies in the summer. Temperatures here range from 14-16°C in the epilimnion (less than 25 feet) and 5-10°C in the hypolimnion (greater than 85 feet). This pattern of seasonal water column use and diel movements has been demonstrated in many similar systems (Goetz 1989). In Flathead Lake, Bull Trout forage in the littoral zone and throughout the water column in fall and spring and move to deep water in summer as water temperatures rise.

Between late April and late June, adult char begin to migrate from the reservoirs toward their natal streams and have been observed to stage at the mouths of spawning tributaries while they mature (City of Seattle 1991; City Light 2011). From mid-September to mid-November, up to several dozen fish have been observed at the mouths of these tributaries (USFWS 2004).

Juvenile char migrate from their natal streams to the reservoir shorelines by age 1, then move offshore into mid-lake feeding areas midsummer at age 1-2 (City of Seattle 1991). They have also been documented congregating in Ross Lake at the mouths of Big Beaver Creek and Devil Creek (USFWS 2004). These areas likely provide foraging for larger juveniles, which feed on small Rainbow Trout, and provide coldwater refuge for juvenile and adult char.

Spawning and Rearing

Char spawn as stream water temperatures decline below 8°C during mid-September through November, peaking in October (City Light 2011). Spawning occurs in the upper Skagit River within British Columbia and in the U.S. areas within Ruby (including tributaries Canyon and Granite), Panther, Lightning, Big Beaver, Little Beaver, Roland, Silver, Pierce, and Devils creeks

of Ross Lake. Within Diablo Lake, most spawning occurs in the Thunder Arm area, including Fisher Creek. In Gorge Lake, spawning occurs in Stetattle Creek and a portion of the Skagit River downstream of the Diablo Dam.

The duration of incubation and emergence timing for char has not been determined for the Skagit area. However, Bull Trout typically have a 100-to-145-day incubation period, and after hatching juveniles remain in the substrate (USFWS 2004). Emergence from the substrate may occur from early April through May depending on water temperatures and increasing stream flows. Generally, once eggs hatch, the fry take approximately 65-90 days to absorb the yolk sac and then spend up to 3 weeks developing parr marks before inflating their air bladder (Fish 2004).

5.2.4.3 Rainbow Trout

Use of the Lake Environment

Rainbow Trout reside in Ross, Diablo, and Gorge lakes and, similar to char, can display an adfluvial life history pattern (City Light 2020). The distribution of Rainbow Trout is mainly determined by food availability, water temperatures, dissolved oxygen, and other environmental and biological factors (Swales 2006). The upper water temperature limits are around 21°C, and the lower limits of dissolved oxygen are around 2.5 mg/L.

Juvenile Rainbow Trout have shown preference towards areas with cover and less prey, versus open areas with higher prey abundance in reservoir environments (Tabor and Wurtsbaugh 1991). Nearshore patches of boulders or submerged vegetation may be important in reducing predation rates and thus increasing survival. Rainbow Trout have been shown to perform localized, seasonal migrations (James and Kelso 1995; Swales 2006). An acoustic telemetry study of 30 Rainbow Trout in a lake in British Columbia found that activity levels were higher in summer than in winter (Watson et al. 2019). During summer, 16 of the 30 fish displayed diel movements where they traveled to a different area of the lake at dawn and returned at dusk. Within the same group of fish, only 4 of the 30 displayed diel movement patterns during the winter. Shallow water areas were the least occupied during summer, while there was no particular preference in winter.

Juvenile Rainbow Trout move from their natal streams to reservoir shorelines by age 1, then move offshore to mid-lake feeding areas consisting of zooplankton in midsummer at age 1 or 2 (City of Seattle 1991; Downen 2014). Age-0 fish forage along the shorelines of reservoirs and stream inlets feeding on young macroinvertebrate larvae. Fry have been observed at Ross Lake's shoreline near stream inlets of Ruby, Lightning, Big Beaver, Roland, Pierce, Devils, Skymo, Little Beaver, and Hozomeen creeks. These stream inlets might also support spawning by Ross Lake trout (City of Seattle 1972). In late spring to early summer, larger fish engage in an annual feeding migration to the mouths of tributary streams to forage and return to the reservoir mid-fall (City of Seattle 1991).

Spawning and Rearing

Rainbow Trout begin migrating to their natal streams between late March and April to spawn. Peak spawning occurs between mid-May and mid-July (City of Seattle 1972). They tend to spawn in the same tributaries as char, although at different times (City Light 2020). Within Ross Lake, spawning locations include the upper Skagit River within British Columbia and within the U.S. in Ruby (including tributaries Canyon and Granite), Panther, Lightning, Big Beaver, Little Beaver, Roland, Silver, Pierce, and Devils creeks. Gorge and Diablo lakes are extremely limited in

spawning and rearing habitats for Rainbow Trout (Downen 2014). Stetattle Creek is the only tributary to Gorge Lake, and Thunder and Colonial creeks are the only tributaries to Diablo Lake with regular spawning.

Fry emergence has been observed in mid- to late August, with hatching likely occurring during the last week of July (City of Seattle 1972). Rainbow Trout rear in waters 10 to 13°C and prefer relatively small, fast-flowing streams containing a high proportion of riffles and pools (City Light 2020). In reservoir environments, juvenile Rainbow Trout can be found in shallow water areas with cover (Tabor and Wurtsbaugh 1991).

5.3 Field Surveys

5.3.1 Ross Lake

Four stranding and trapping field surveys were conducted on Ross Lake. Three surveys were conducted using the ACS method during October 5-6 (Figure 5.3-1A) and October 26-27, 2021 (Figure 5.3-1B), and April 7, 2022 (Figure 5.3-1C). One additional, opportunistic survey was conducted in September 2022 (Figure 5.3-1D), using the reconnaissance census approach. Approximate extent of coverage of these surveys, observations of potential stranding and trapping features, and direct observations of fish stranding or trapping are summarized visually in Attachment A (Figures A-1a through A-1j). Observations of fish stranding or strapping are summarized in Table 5.3-1.

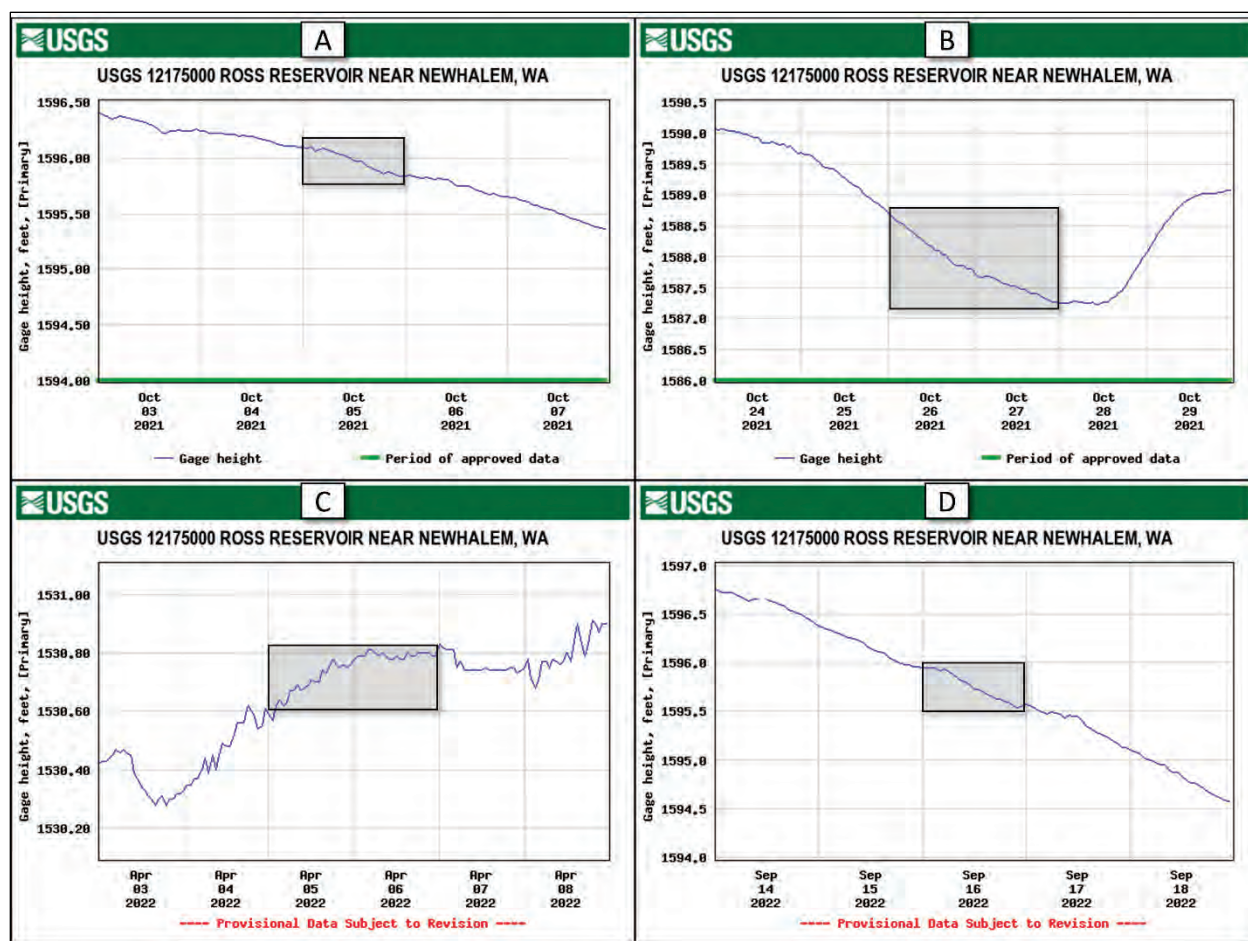


Figure 5.3-1. Ross Reservoir (i.e., Ross Lake) WSE (feet above CoSD) at the time of field surveys on October 5, 2021 (A), October 26-27, 2021 (B), April 5-6, 2022 (C), and September 16, 2022 (D) (USGS 2022a). Shaded rectangular boxes indicate approximate periods of reconnaissance surveys.

Table 5.3-1. Observations of fish stranding and trapping observed during field surveys.

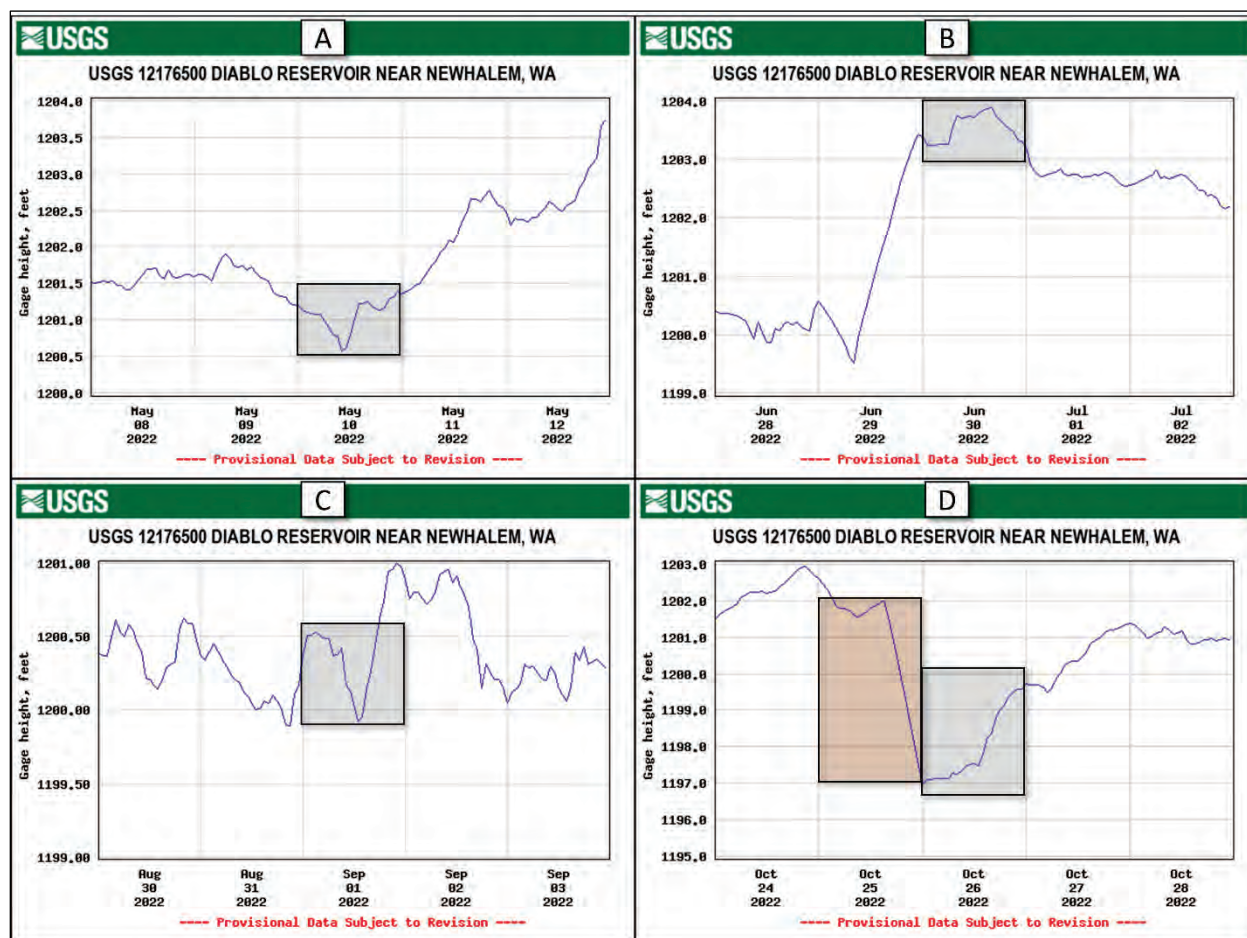
Date	Survey Area	Survey Type	Species	Life Stage	Count	Status
9/16/2020	Diablo, Thunder Arm	Opportunistic Reconnaissance	Rainbow Trout	Fry	4	Live
9/17/2020	Diablo, Thunder Arm	Opportunistic Reconnaissance	Rainbow Trout	Fry	22	7 live, 15 dead
12/17/2020	Ross, 1 mi S of Border E	Reconnaissance	None	N/A	0	N/A
12/18/2020	Ross, 1 mi S of Border W, mouth of Big Beaver Cr	Reconnaissance	None	N/A	0	N/A
3/24/2021	Ross, Lightning Cr, Big Beaver Cr, around Lost Lake, Roland Cr, within Ruby Arm	Reconnaissance	None	N/A	0	N/A
4/20/2021	Ross, Little Beaver Cr, Arctic Cr, around Lost Lake, Lightning Cr	Reconnaissance	None	N/A	0	N/A
10/5/2021	Ross, 1 mi S of Border (E and W), 2 mi S of Border (E and W), Silver Cr, Little Beaver Cr, Arctic Cr, Lost Lake, Lightning Cr, Dry Cr, Big Beaver Cr, Roland Cr, Ruby Arm	Drawdown	None	N/A	0	N/A
10/26/2021	Ross, Big Beaver Cr	Drawdown	None	N/A	0	N/A
10/26/2021	Ross, 1 mi S of Border W	Drawdown	Redside Shiner	Juvenile	2	Mortalities
10/26/2021	Ross, 1 mi S of Border E	Drawdown	Brook Trout*	Adult	1	Live
10/27/2021	Ross, Silver Cr, Lost Lake, Lightning Cr, Roland Cr	Drawdown	None	N/A	0	N/A
10/27/2021	Ross, Dry Cr	Drawdown	Redside Shiner	Fry	5	Live
10/27/2021	Ross, Dry Cr	Drawdown	Unidentifiable salmonid	Fry	1	Live
4/7/2022	Ross, 1 mi S of Border (E and W), 2 mi S of Border (E and W), Little Beaver Cr, Arctic Cr, Lost Lake, Lightning Cr, Dry Cr, Big Beaver Cr, Roland Cr, Ruby Arm	Drawdown	None	N/A	0	N/A
4/7/2022	Ross, Silver Cr	Drawdown	Redside Shiner	Fry	100	Live
5/10/2022	Diablo, Thunder Arm, Colonial Cr, Buster Brown Bay, Dry Dock Bay	Quarterly	None	N/A	0	N/A
5/10/2022	Gorge, Reflector Bar	Quarterly	Rainbow Trout	Fry	2	Live
5/10/2022	Gorge, Reflector Bar	Quarterly	Unidentified salmonids	Fry	5-10	Live
6/30/2022	Diablo, Thunder Arm, Colonial Cr, Buster Brown Bay, Dry Dock Bay	Quarterly	None	N/A	0	N/A
6/30/2022	Gorge, Reflector Bar	Quarterly	None	N/A	0	N/A
8/29/2022	Diablo, Thunder Arm, Colonial Cr, Buster Brown Bay, Dry Dock Bay	Quarterly	None	N/A	0	N/A

Date	Survey Area	Survey Type	Species	Life Stage	Count	Status
8/29/2022	Gorge, Reflector Bar	Quarterly	None	N/A	0	N/A
9/18/2022	Ross, Hozomeen	Opportunistic	None	N/A	0	N/A
10/26/2022	Diablo, Thunder Arm, Colonial Cr, Rhode Cr, Buster Brown Bay, Dry Dock Bay	Quarterly	Rainbow Trout	Fry	122	109 live, 13 dead
10/26/2022	Gorge, Reflector Bar	Quarterly	None	N/A	0	N/A

* Species identification presumed, based on location, size, behavior, and markings.

5.3.2 Diablo and Gorge Lakes

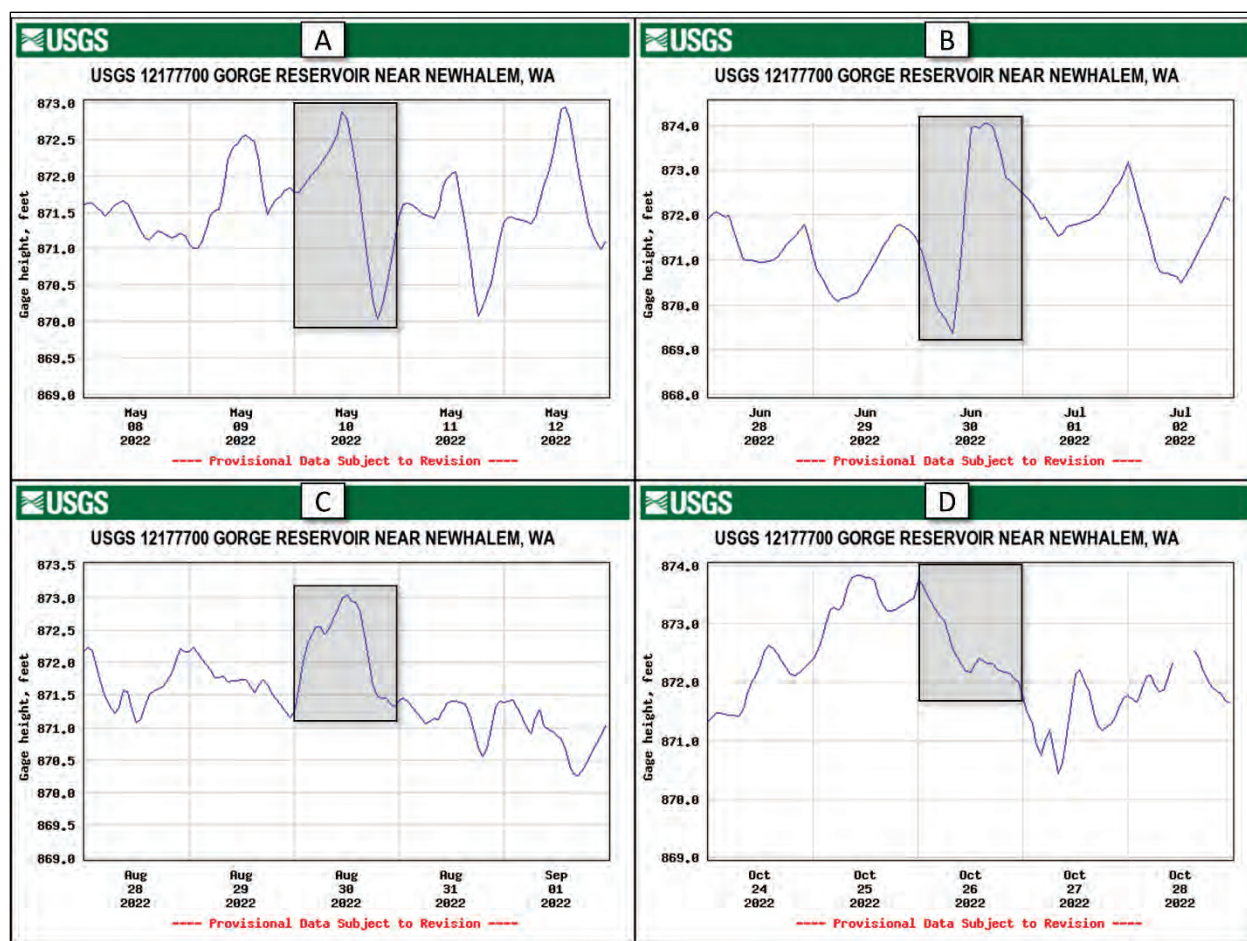
Four stranding and trapping field surveys were conducted on Diablo Lake using the reconnaissance census approach (Figure 5.3-2). The first three were conducted during normal operations, and the fourth directly after a reservoir drawdown. Approximate extent of coverage of these surveys, observations of potential stranding and trapping features, and direct observations of fish stranding or trapping are summarized visually in Attachment B (Figure B-1).



Note: Gray shaded rectangular boxes indicate approximate periods of reconnaissance surveys; orange shaded box in panel D draws attention to the approximately 5 foot drawdown that occurred the day prior to the October 26 survey.

Figure 5.3-2. Diablo Reservoir (i.e., Diablo Lake) WSE (feet above CoSD) at the time of field surveys on May 10, 2022 (A), June 30, 2022 (B), September 1, 2022 (C), and October 26, 2022 (D, USGS 2022b).

Four stranding and trapping field surveys were conducted on Gorge Lake using the reconnaissance census approach (Figure 5.3-3). Approximate extent of coverage of these surveys, observations of potential stranding and trapping features, and direct observations of fish stranding or trapping are summarized visually in Attachment B (Figure B-2).



Note: Shaded rectangular boxes indicate approximate periods of reconnaissance surveys.

Figure 5.3-3. Gorge Reservoir (i.e., Gorge Lake) WSE (feet above CoSD) at the time of field surveys on May 10, 2022 (A), June 30, 2022 (B), August 30, 2022 (C), and October 26, 2022 (D, USGS 2022c).

5.4 Ross Lake Longitudinal Water Surface Elevation Profile

Water surface elevation measurements collected at the water's edge around Ross Lake are shown in Figure 5.4-1. Elevations are plotted at their latitude within the lake, along with an overview map of Ross Lake to visualize the location of each measurement, the elevation of each measurement, and the reference WSE measured at Ross Dam.

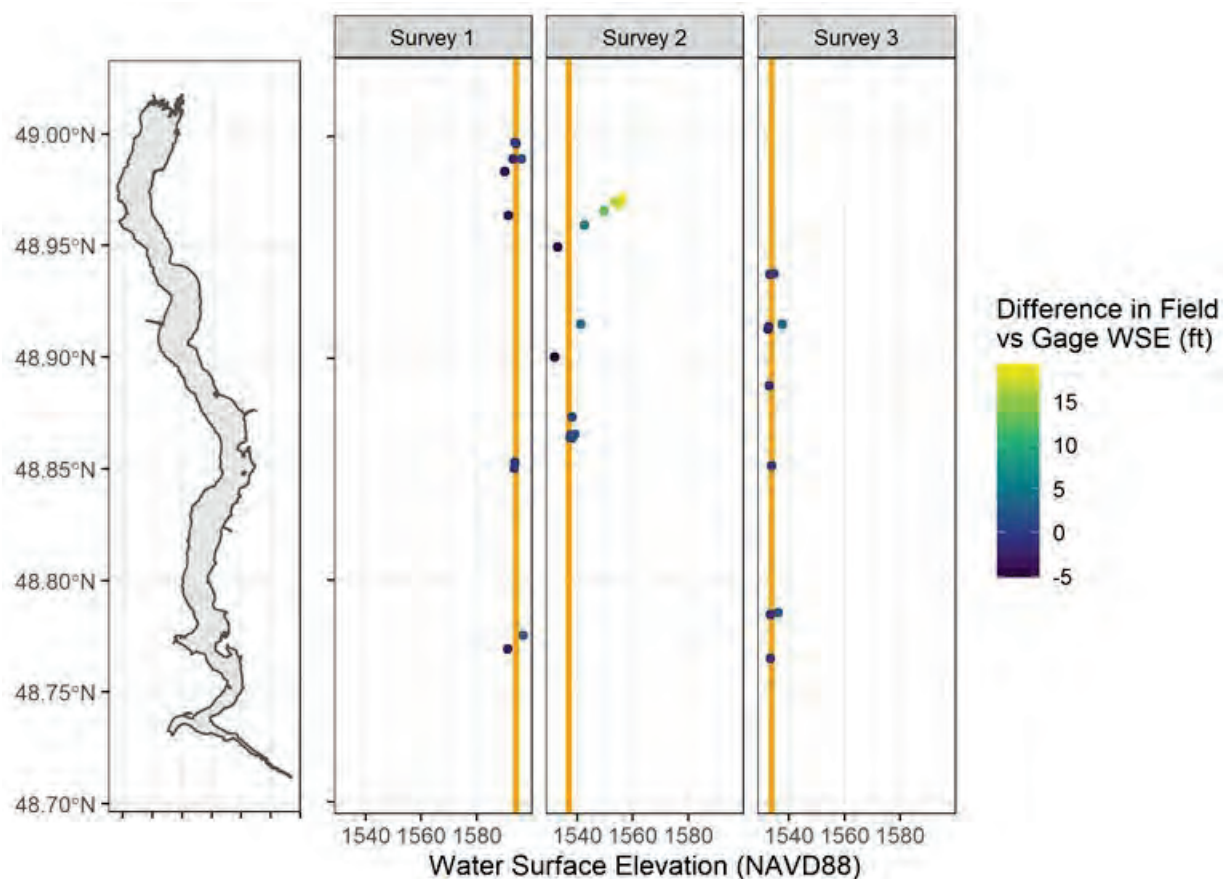


Figure 5.4-1. Reference map of Ross Lake (left panel), plotted alongside the water’s edge location (latitude) and water surface elevation (WSE) during three field surveys. Vertical orange lines in panels for each survey indicate the reference WSE as measured at Ross Dam (USGS Gage 12175000). Field WSE was calculated using DEM elevation at the water’s edge location recorded in the field.

The field surveys encompass a relatively narrow band of elevations focused around 1,530 feet and 1,590 feet NAVD 88 (1,523.7feet and 1,583.7feet CoSD, respectively; Figure 4.3-6), and the observations from May 2022 (“Survey 3” in Figure 5.4-1) were from a survey that did not extend to the northernmost reaches of the reservoir.

It appears that when WSE is near the 2022 seasonal maximum (1,608.9 NAVD 88, 1,602.6 feet CoSD), the reservoir is essentially flat. As WSE approaches the 2022 seasonal minimum (1,529.0 feet NAVD 88, 1,522.7 feet CoSD), the reservoir is still essentially flat as far north as approximately 48.95°N, near Jack Point. However, at this point in drawdown, the water level within Ross Lake steeply rises around Silver Creek and is close to 30 feet higher in the regions of the upper reservoir. This profile corresponds with model-predictions presented in Section 4.2.5 (Figure 4.2-2) for a reservoir drawdown scenario when WSE is below the spillway crest.

6.0 DISCUSSION AND FINDINGS

This study is complete and has met the goals and objectives stated in Section 2.0, which were to assess the risk of stranding and trapping native fish species within the study area under normal Project operations.

6.1 Status of June 9, 2021 Notice

The June 9, 2021 Notice noted four items of discussion related to the implementation of this Stranding and Trapping Assessment. The status of each is summarized in Table 6.2-1.

Table 6.2-1. Status of Stranding and Trapping Assessment modifications identified in the June 9, 2021 Notice.

Study Modifications Identified in the June 9, 2021 Notice: As Written	Status
City Light to hold technical meetings with the LPs to review initial information to assess adequacy of that information in informing stranding evaluation (including tree size).	City Light held a technical meeting with the LPs in October 2021 to review initial information to assess adequacy of information related to the spatial scale of data in informing stranding evaluation (including tree size).
Review 2021 sampling in U.S. for risk assessment to refine and inform the expansion to Canadian drawdown zone in 2022.	The GIS risk assessment study area includes the drawdown area in Canada.
LPs requested that the study results inform the development of PME's inclusive of a reservoir drawdown rate that avoids, limits, or greatly reduces stranding of fish and juvenile amphibians; and identifies reservoir elevations that prove problematic for trapping of fish and juvenile amphibians.	City Light and LPs understood that this study report would not include proposed PME measures related to stranding and trapping, which it does not as the observed incidence of stranding and trapping was insubstantial. The information presented in this study report provides data necessary to develop such PME's, as necessary.
City Light to clarify the methods section of this report that if maintenance drawdowns or lowering of reservoirs beyond normal operations occurs, City Light will attempt to perform opportunistic surveys as safety procedures allow.	City Light has clarified in the methods section of this report that if maintenance drawdowns or lowering of reservoirs beyond normal operations occurred, crews would attempt to perform opportunistic surveys as safety procedures allowed. Opportunistic surveys, where appropriate, were conducted during this study consistent with the RSP.

6.2 Interpretation of Findings

Desktop analyses for the three Project reservoirs identified patches of low slope and sink features that may present a risk for fish stranding and trapping. However, field surveys generally failed to document the occurrence of fish stranding or trapping within these features, with a few notable exceptions. In general, three factors must co-occur for fish stranding or trapping to occur:

- (1) Topographic features that present a risk to fish must be present. *This may be thought of as the **topographic** aspect of risk.*

- (2) Reservoir WSE must exhibit the appropriate level, direction of change (refill versus drawdown), and rate of change (e.g., drawdown rate) to dewater the topographic features in such a way that fish may become stranded or trapped. *This may be thought of as the hydrologic aspect of risk.*
- (3) Individual fish of the correct species and life stage must be present near these features at the time of dewatering to become stranded or trapped. *This may be thought of as the biological aspect of risk.*

This study demonstrated that the first factor, the topographic aspect, is present to varying degrees at specific locations around each Project reservoir. These locations tend to be alluvial fans and river deltas near the mouth of tributaries flowing into each lake, although they also include backwater, low-gradient areas above infrastructure (e.g., the SR 20 causeway across Gorge Lake). These features may become exposed (the hydrologic aspect) during Project operations and can present a risk to fish if present. However, the intersection of the topographic, hydrologic, and biological aspects of the risk of stranding and trapping do not appear to occur regularly.

This intersection of risk factors differs among reservoirs. Ross Lake is generally dewatered once per year, with small fluctuations occurring during the summer months when the lake is nearly full. The small fluctuations have the potential to create a risk at a time of the year when susceptible life stages of fish are present, however, based on field observations, the degree to which this actually occurs appears to be small. The annual drawdown of Ross Lake occurs with a seasonality that means the greatest areas for stranding and trapping are generally dewatered gradually, over a period of time when juvenile fish are not concentrated around these features (mid-winter). Although logistical constraints prevented accessing all sites around Ross Lake during January and February, no observations of fish stranding or trapping were recorded during winter and early spring reconnaissance surveys around Ross Lake in December 2020 and late March 2021, both of which occurred after a drop in reservoir WSE. The greatest biological risk for stranding or trapping native char (*Salvelinus spp.*) around Ross Lake may be during July, when juveniles are outmigrating from tributaries. However, during the end of July, Ross Lake is at or near maximum WSE. Other than during emergency drawdowns, this does not appear to be a season when high-risk areas are expected to be dewatered. For native trout (*O. mykiss*), the greatest biological risk may be around mid-September to mid-October, when juveniles are leaving the tributaries. October is generally near the beginning of the seasonal drawdown for flood risk management, when features near the top stratum of elevation within the Ross Lake varial zone would be exposed, so this would seem to be an intersection of all three risk aspects. However, surveys conducted during early and late October 2021 and mid-September 2022 identified no instances of stranding or trapping of native trout.

Diablo and Gorge lakes do not exhibit the same degree of seasonality to their drawdown as Ross Lake. Consequently, the risk of stranding and trapping within those reservoirs tends to be more stochastic. The two substantial salmonid stranding and trapping events observed occurred around Diablo Lake during autumn (September 2020 and October 2022), when juvenile fish are concentrated near tributary mouths, after an operational drawdown of six or more feet within a single day. Similarly, fish stranding was observed during the May 2022 survey of Gorge Lake, when the stranding risk areas described above (Section 5.2.3.2) between 877-878 feet NAVD 88 (870.5-871.5 feet CoSD) had recently been dewatered during a nearly three-foot operational

drawdown. Consequently, the intersection of topographic, hydrologic, and biological risk factors may occur with greater frequency around Diablo and Gorge lakes than Ross Lake.

Finally, because the shape of the longitudinal profile of Ross Lake throughout the drawdown cycle is still not known with certainty, the relationship between water surface elevation at the lower and upper ends of the lake is unclear. This means that stranding and trapping features identified at the upper end of Ross Lake may not dewater as rapidly as downstream sites closer to Ross Dam. Consequently, the stranding and trapping risk that emerges from the intersection of topography and hydrology at these upper Ross Lake sites may be overestimated.

6.3 Integration of DEM, Drawdown, and Fish Periodicity Analyses

In Ross Lake, the greatest risk of stranding and trapping is concentrated in areas within the upper 25 percent elevation stratum of reservoir shoreline. This is due to a combination of high-risk feature areas (topographic risk) and the frequency of drawdown events as the reservoir fluctuates around the annual maximum WSE and through the beginning of the annual reservoir drawdown as fall rain events periodically increase WSE (hydrologic risk). Drawdown events in the upper 5 percent of normal WSE happen most frequently between July and September.

Stranding and trapping threats are anticipated to be greatest for early-emerging fry and juveniles of Rainbow Trout, Bull Trout, and Dolly Varden from April through the summer and early fall (biological risk). The dangers of trapping may extend beyond the summer months for juveniles and older subadults. During these periods, the reservoir is generally full to support reservoir recreation.

The greatest biological risk for native char fry likely occurs when they move from streams into the reservoirs from late spring into July. Char fry entering Ross Lake from streams with a high amount of topographic risk features where they enter the reservoir, such as Hozomeen or Silver creeks, may encounter stranding or trapping features during this sensitive life stage. However, the actual risk profile at locations around Hozomeen and Silver Creek is generally mitigated by hydrology: Ross Lake is usually near full at this time of year, meaning that these fry do not actually interact with stranding or trapping features during their first few months of reservoir residency, and wouldn't encounter such features until water levels begin receding in the fall. On the other hand, char fry entering Ross Lake from tributaries such as Ruby Creek would generally not encounter stranding or trapping features (topographic risk), due to the lack of high-risk terrain near those stream mouths at those elevations.

In contrast, the greatest biological risk period for Rainbow Trout fry would be around September thru October, as they move from streams into the reservoirs. Hydrologic and topographic aspects of the risk of stranding and trapping also appear to be elevated during this time of year. This means that fry entering Ross Lake from tributary streams during September/October are more likely to encounter potential stranding and trapping topography during dewatering at this time of year. This intersection of a sensitive life stage, seasonal behaviors, water surface elevation, and topography may present a risk for Rainbow Trout in mid-fall at locations such as near the mouth of Hozomeen and Little Beaver creeks.

While the upper elevations of shoreline within the drawdown zone contain the greatest topographic risk around Ross Lake, high-risk areas are also present in the shoreline within the bottom 25 percent elevation stratum of operational WSE. Although the water level in Ross Lake does not

draw down to those elevations annually, it has drawn down sufficiently to disconnect Skagit River side channels and expose large sink areas at least twice during the 11-year period of record. Reservoir drawdowns within this elevation range (i.e., approaching the annual minimum WSE) tend to occur in mid- to late spring (April-May). This is not generally a high-risk period for native char, as they have just begun to emerge in streams and have not yet moved down into the reservoir. Rainbow Trout are generally spawning during late spring (May), during which the potential for stranding or trapping appears to be low. However, it bears noting that these areas may still pose a risk to other fishes. For example, Redside Shiner were observed in high numbers at Silver Creek during field surveys in April 2022. Although Redside Shiner are not a native species of concern, this observation suggests that at least certain species may be susceptible to stranding under similar conditions.

In Diablo Lake, Thunder Arm is the zone with the largest area of potential stranding and trapping topography and the only location within the reservoir where regular native char and Rainbow Trout spawning activity has been documented. The upper two-thirds of Thunder Arm is frequently dewatered throughout the year, with the highest potential risk areas in the Thunder Arm at 1,207-1,208 feet NAVD 88 (1,200.6-1,201.6 feet CoSD). The overall risk is slightly lower to native char in July, because drawdowns below this elevation occur less frequently during summer, when this sensitive life stage is emigrating from tributaries into the lake. The overall risk is higher in April, when fry that have emerged within tributaries could be present in inlet mouths, and in September and October, when Rainbow Trout fry are moving out of streams and into the main reservoir. This confluence of risk features apparently emerged during the September 2020 reconnaissance survey stranding event, and again in October 2022 when field surveys occurred the day after a 5-foot drawdown. In the latter case, a high proportion of low-slope area was exposed by this drawdown, and at least 120 fish were observed stranded or trapped in many small pools near the mouths of Rhode and Colonial creeks (Figure 6.3-1). One larger pool at the mouth of Colonial Creek had at least 50 fish trapped in a few inches of water. These pools were too small to be identified in the sink analysis; however, they were located in areas identified as low-slope hazards. Due to their small size, the amount of standing water in such pools would be negligible, and these areas would likely function more like a stranding hazard than a trapping pool.

In Gorge Lake, the greatest amount of potential risk areas was concentrated at 875-878 feet NAVD 88 (868.5-871.5 feet CoSD). Most of the trapping risk was concentrated close to the SR 20 causeway, while frequently exposed low slope areas were found in wider sections of the lake from the causeway to Gorge Dam. While the bulk of the potential risk areas are found in shallow areas in the middle of the reservoir, there is a noticeable amount of low-slope area around the mouth of Stetattle Creek (the only tributary with regular spawning recruitment to Gorge Lake). It is inundated and dewatered throughout the year, with relatively fewer events in the fall and winter when the water level reaches normal maximum WSE less frequently. This drawdown pattern could pose a greater risk to native char exiting Stetattle Creek in July than to Rainbow Trout exiting in October, but as drawdown events occur throughout the year both species could be impacted in this area of the reservoir.

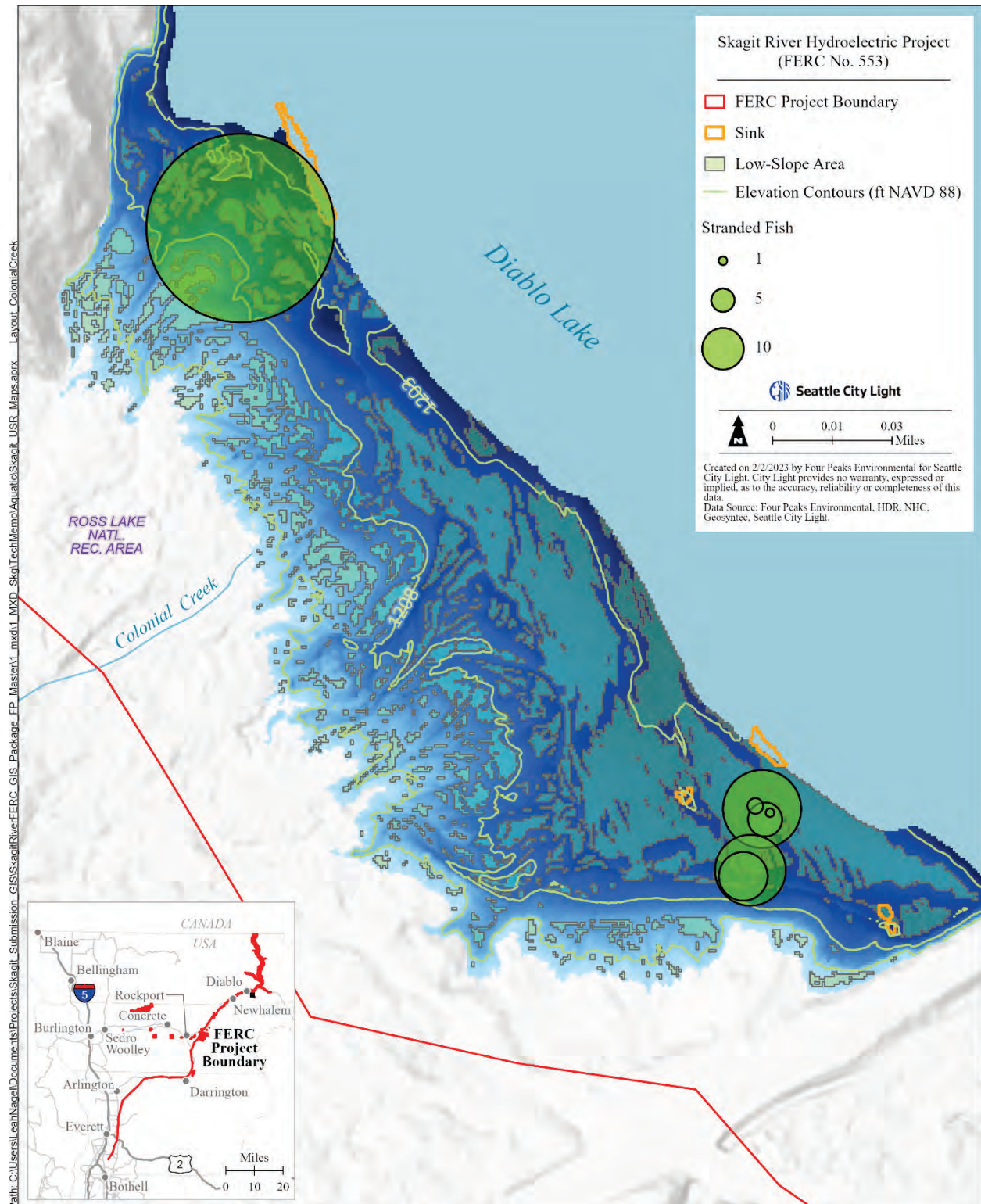


Figure 6.3-1. Stranded fish observations at the mouth of Colonial Creek during the October 2022 survey of Diablo Lake.

Due to the lack of data between approximately 868-876 feet NAVD 88 (861.5-869.5 feet CoSD) in the lower section of Gorge Lake (downstream of the SR 20 bridge, the approximate downstream extent of the 2018 green LiDAR flight), the extent of low slope and sink area in that portion of the reservoir is unknown. While much of the terrain is relatively steep, there may be more frequently-dewatered potential risk areas where tributaries enter the reservoir, particularly at the mouth of Gorge Creek. However, the total area of this missing elevation information is 3.5 acres, which is relatively modest in size compared to the total varial zone. Field observation of the varial zone at the mouth of Gorge Creek suggests there are, at best, a few hundred square feet of terrain with stranding and trapping topographic features.

In conclusion, the shoreline around each Project reservoir contains topographic features that have been associated with stranding and trapping in other reservoirs, and these features are regularly exposed during Project operations. Based on field observations to date, however, the occurrence of fish stranding and trapping among the areas with these features has been very limited. Within Ross Lake, this is likely due to the rate and timing of drawdown. Drawdown rates from the 2011 to 2021 record average 0.4 feet per day (approximately 0.2 inch/hour) (standard deviation = 0.2 feet per day [approximately 0.1 inch/hour]), and in most years drawdown does not dewater potential stranding and trapping features during sensitive periods of the life history of resident fishes. Greater potential for fish stranding and trapping exists around Diablo and Gorge lakes than in Ross Lake, due to the greater extent of the intersection of the risk aspects associated with hydrology, topography, and biology. However, the actual occurrence of such phenomena was limited to three instances, each of which followed a reservoir drawdown during spring or fall months. This report summarizes the results of a study spanning three seasons (slightly more than two calendar years), in which substantial institutional knowledge was accrued, enabling rapid and adaptive study refinements. If future monitoring of the occurrence of stranding and trapping occurs, these results will provide invaluable information to improve survey efficiency and effectiveness, by enabling field staff to focus efforts on the locations, times of year, and operational conditions most likely to create fish stranding or trapping.

7.0 VARIANCES FROM FERC-APPROVED STUDY PLAN AND PROPOSED MODIFICATIONS

As stated in the Stranding and Trapping Assessment Interim Report (City Light 2022), two variances from the FERC-approved study plan were adopted during study implementation. As part of continued study implementation after filing of the ISR, two additional variances were adopted. Notwithstanding these variances, the goals and objectives of the study plan were achieved. These variances are summarized below.

Variances identified in the Stranding and Trapping Assessment Interim Report:

- (1) **Field Sampling Approach:** The SRS and ACS approach to field sampling design was not used when Ross Lake was near normal maximum WSE, and the area of varial zone to be surveyed was small. Instead, given the narrow band of varial zone that was exposed, a comprehensive census of the entire littoral zone was undertaken instead of random sampling. This was a positive variance that did not compromise study goals or objectives, because a greater proportion of the exposed habitat with risk features was ultimately sampled than would have been following the SRS-ACS approach.
- (2) **Field Data Collected:** The types of data collected from potential trapping pools and low gradient stranding areas were refined during field reconnaissance to enable staff to sample a greater proportion of the dewatered varial zone while minimizing collection of data that does not feed directly into subsequent analyses. Data collected when surveying features that presented a potential stranding or trapping risk were refined from the list in Section 2.6.3.2 of the RSP as detailed in Table 7.0-1. LPs were notified of this change during the October 2021 working session, which presented the results and observations of the Ross Lake reconnaissance events during the 2020/2021 drawdown cycle and lessons learned for the 2021/2022 surveys.

Table 7.0-1. Refined data collected during field surveys under each scenario.

Data to be Collected for Every Quadrat	Additional Data to be Collected per each Scenario		
	If Potential Stranding or Trapping Feature Observed	If Evidence of Predation Observed	If Stranded or Trapped Fish Present (All Parameters Collected for Each Species and Life Stage)
1. Date and time of observations	9. Photograph of stranding and trapping feature and bearing of view	14. Description of predator or sign	16. Species
2. Reservoir and survey area	10. Distance to open water	15. Photograph or predator or sign	17. Status (Live/Dead)
3. Weather	11. Length of potential stranding/trapping feature		18. Photograph
4. Survey team members	12. Width of potential stranding/trapping feature		19. Life Stage
5. Quadrat ID	13. Maximum depth of potential stranding/trapping feature		20. Count
6. Latitude and longitude coordinates of observation			
7. Photograph of quadrat and bearing of view			
8. Additional Notes			

The following data, listed in Section 2.6.3.2 of the RSP, were not collected for reasons described in Table 7.0-2.

Table 7.0-2. Data mentioned in RSP that are not being collected, and rationale for omission.

Data Listed in RSP That Are Not Being Collected	Rationale for Omission
Water temperature	Drawdown occurs during cool periods when temperature is not likely a factor contributing to mortality. No methodology described to incorporate this information into risk assessment.
Dissolved oxygen concentration	Measuring DO at every potential trapping pool would slow crews down and prevent more extensive sampling of a broader area that could otherwise better document the full extent of potential stranding and trapping. No methodology described to incorporate this information into risk assessment.
Turbidity	Measuring turbidity at every potential trapping pool would slow crews down and prevent more extensive sampling of a broader area that could otherwise better document the full extent of potential stranding and trapping. No methodology described to incorporate this information into risk assessment.
Dominant and subdominant sediment grain size	Unclear how this informs a risk assessment. More appropriate for a model of factors contributing to stranding and trapping. No methodology described to incorporate this information into risk assessment.
Distance from instream cover	Unclear how this informs a risk assessment. More appropriate for a model of factors contributing to stranding and trapping. No methodology described to incorporate this information into risk assessment.
Presence of canopy cover	Unclear how this informs a risk assessment. More appropriate for a model of factors contributing to stranding and trapping. No methodology described to incorporate this information into risk assessment.
Presence of macroinvertebrates	Unclear how this informs a risk assessment. More appropriate for a model of factors contributing to stranding and trapping. No methodology described to incorporate this information into risk assessment.
Field measured slope	Unclear how this informs a risk assessment. More appropriate for a model of factors contributing to stranding and trapping. No methodology described to incorporate this information into risk assessment.
Unusual hydraulic conditions	Unclear how this informs a risk assessment. More appropriate for a model of factors contributing to stranding and trapping. Vague as described. No methodology described to incorporate this information into risk assessment.
Presence of macrophytes	Unclear how this informs a risk assessment. More appropriate for a model of factors contributing to stranding and trapping. No methodology described to incorporate this information into risk assessment.
Reservoir drawdown rate at time of field survey	Information will be incorporated by reporting reservoir drawdown rate in written reports. Data reporting at gage is delayed, so field reporting would be inaccurate.

Additional Variances Adopted Post-ISR Filing:

- (1) **Survey Timing for Diablo and Gorge Lakes:** Surveys on Diablo and Gorge lakes were proposed to be performed quarterly according to the study plan. However, this plan was refined based on fish periodicity information to target times of the year when fish were more likely to be present and observable. Consequently, the Q1 survey was shifted to occur during Q2, and thus two surveys were conducted in Q2, one in Q3, and one in Q4.
- (2) **Missing Elevation Strata:** While most of the varial zone around each Project reservoir was analyzed, data characterizing each reservoir were missing narrow elevation strata within the operational range of WSE. In each case, while these missing data may have led to an underestimation of the total amount of potential stranding or trapping features, the data gaps did not compromise the overall assessment of the risk of stranding and trapping of native fish species. The missing elevation stratum around Ross Lake (below 1,494.3 feet NAVD88 [1,488 feet CoSD]) may include stranding and trapping features, but this elevation range does not appear to be regularly dewatered under normal Project operations, as it was exposed only once during the 2011-2022 period of record. Analyses of Diablo Lake focused on Thunder Arm, where data were comprehensive; study reconnaissance indicates that this region contains the greatest concentration of stranding and trapping risk around that reservoir. For Gorge Lake, the missing elevation stratum (approximately 868.5-877.5 feet NAVD88 [862-871 feet CoSD]) extends one foot into the normal operating range of Gorge Lake. It is possible that stranding and trapping features within this stratum were not detected, but the magnitude of these omissions is spatially constrained. Consequently, the study objective of “[i]dentify[ing] and map[ping] focal areas... where stranding and trapping risk to native fish species may occur,” was still met.

Notwithstanding these variances, the study goals and objectives were achieved and the Stranding and Trapping Assessment is consistent with the FERC-approved study plan.

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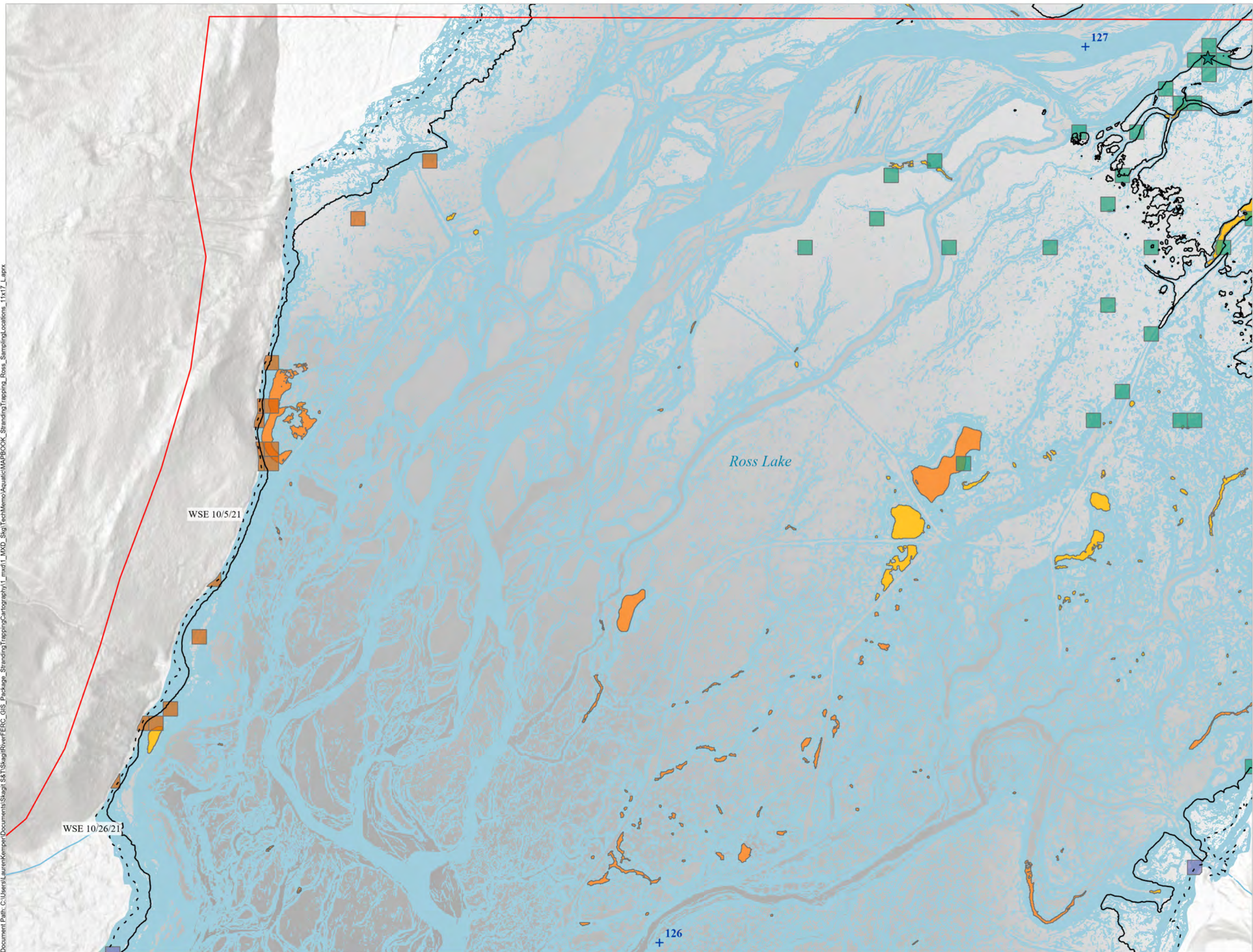
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RESERVOIR FISH STRANDING AND TRAPPING RISK ASSESSMENT

ATTACHMENT A

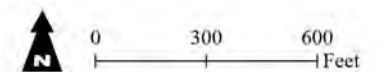
MAPS OF SAMPLING LOCATIONS ON ROSS LAKE

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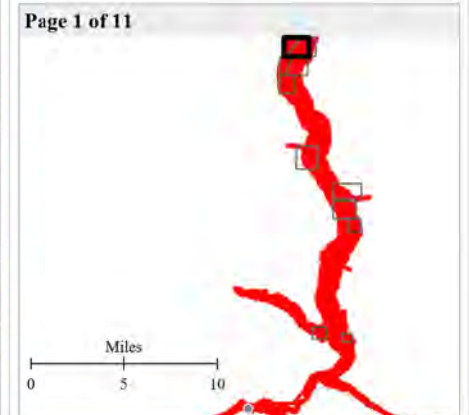


**FA-03 S&T RISK ASSESSMENT
FIGURE A-1A
ROSS LAKE: ROSS 1 MILE
WEST SAMPLING LOCATIONS**

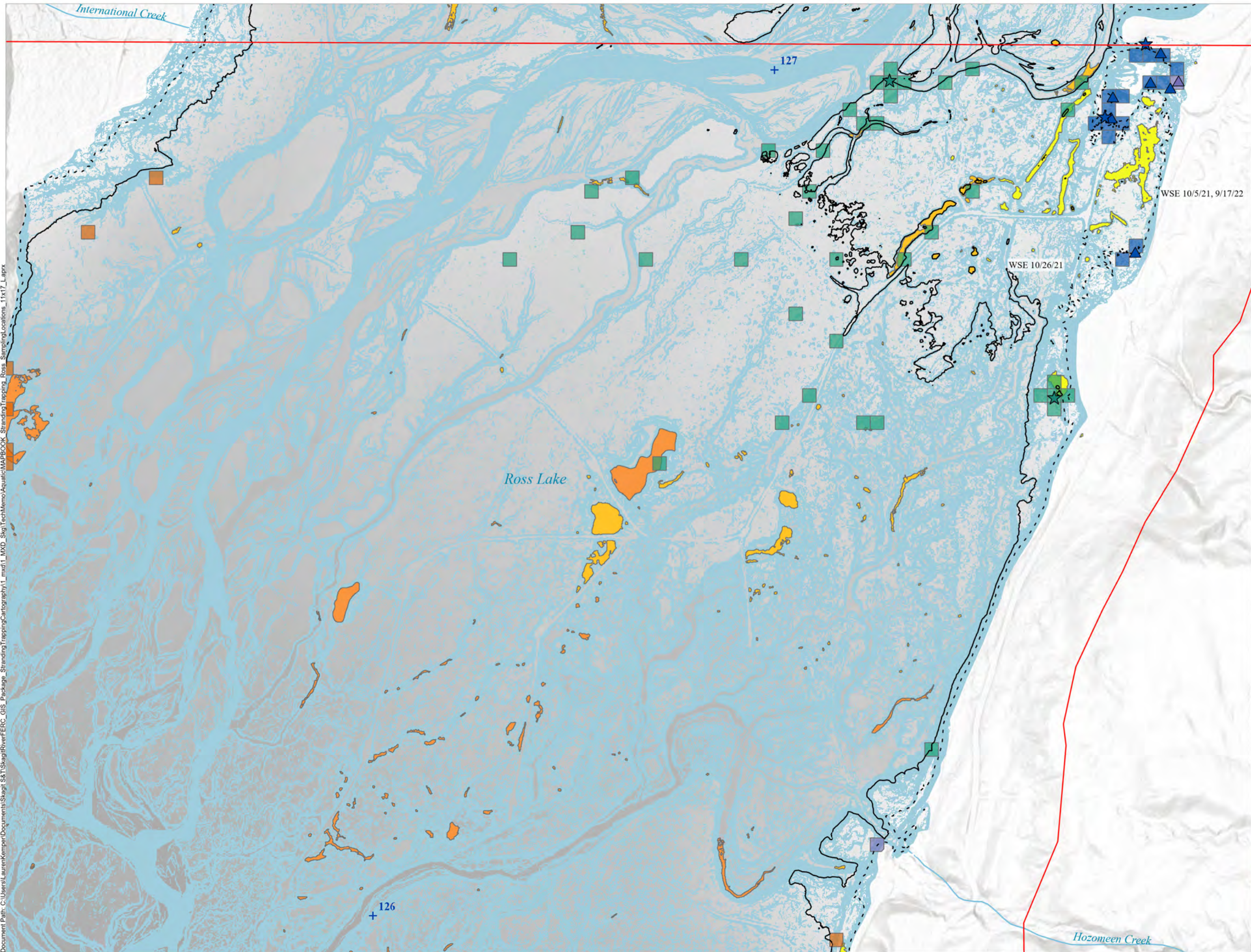
- FERC Project Boundary
- Project River Miles (PRM)
- Sink Elevation (ft NAVD 88)
 - 1494 - 1506
 - 1506 - 1519
 - 1519 - 1532
 - 1532 - 1545
 - 1545 - 1558
 - 1558 - 1570
 - 1570 - 1583
 - 1583 - 1596
 - 1596 - 1609
- Low Slope Elevation (ft NAVD 88)
 - 1609
 - 1493
- Sampling Location
 - 10/5/21
 - 10/26/21
 - 10/27/21
- Observed S&T Fish
 - 10/26/21
- Water Surface Elevation
 - 10/26/21
 - 10/5/21



Page 1 of 11

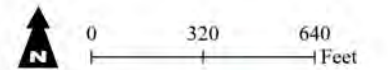


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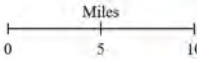
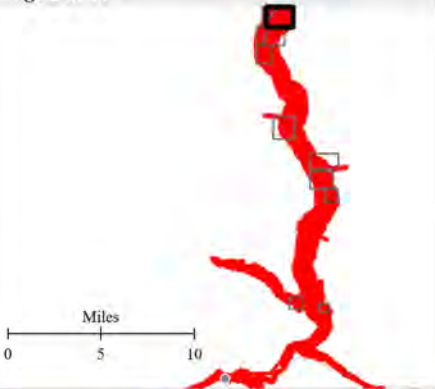


FA-03 S&T RISK ASSESSMENT
FIGURE A-1B
ROSS LAKE: ROSS 1 MILE
EAST SAMPLING LOCATIONS

- FERC Project Boundary
- Project River Miles (PRM)
- Sink Elevation (ft NAVD 88)
 - 1494 - 1506
 - 1506 - 1519
 - 1519 - 1532
 - 1532 - 1545
 - 1545 - 1558
 - 1558 - 1570
 - 1570 - 1583
 - 1583 - 1596
 - 1596 - 1609
- Low Slope Elevation (ft NAVD 88)
 - 1609
 - 1493
- Sampling Location
 - 10/5/21
 - 10/26/21
 - 10/27/21
 - 9/17/22
- Potential S&T Zone
 - 10/5/21
 - 9/17/22
- Observed S&T Fish
 - 10/26/21
 - 9/17/22
- Water Surface Elevation
 - 10/26/21
 - 10/5/21



Page 2 of 11



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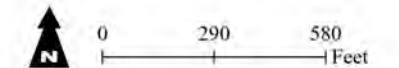
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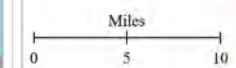
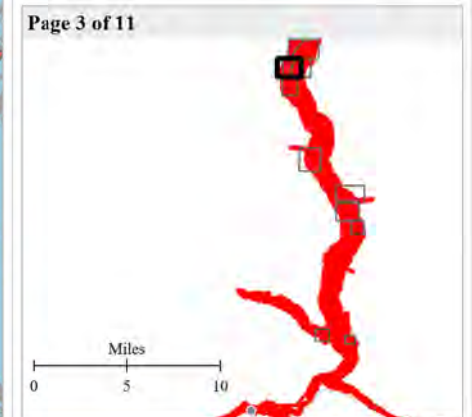
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FA-03 S&T RISK ASSESSMENT
FIGURE A-1C
ROSS LAKE: ROSS 2 MILE
WEST SAMPLING LOCATIONS

- FERC Project Boundary
+ Project River Miles (PRM)
- Sink Elevation (ft NAVD 88)
- 1494 - 1506
 - 1506 - 1519
 - 1519 - 1532
 - 1532 - 1545
 - 1545 - 1558
 - 1558 - 1570
 - 1570 - 1583
 - 1583 - 1596
 - 1596 - 1609
- Low Slope Elevation (ft NAVD 88)
- 1609
 - 1493
- Sampling Location
- 10/5/21
 - 10/27/21
 - 4/7/22
- Water Surface Elevation
- 10/26/21
 - 10/5/21



Page 3 of 11



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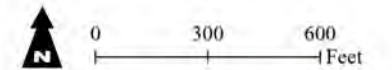
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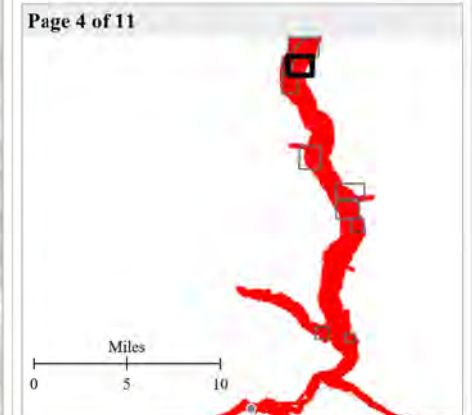


**FA-03 S&T RISK ASSESSMENT
FIGURE A-1D
ROSS LAKE: ROSS 2 MILE
EAST SAMPLING LOCATIONS**

- FERC Project Boundary
- Project River Miles (PRM)
- Sink Elevation (ft NAVD 88)
 - 1494 - 1506
 - 1506 - 1519
 - 1519 - 1532
 - 1532 - 1545
 - 1545 - 1558
 - 1558 - 1570
 - 1570 - 1583
 - 1583 - 1596
 - 1596 - 1609
- Low Slope Elevation (ft NAVD 88)
 - 1609
 - 1493
- Sampling Location
 - 10/5/21
 - 10/27/21
 - 4/7/22
- Water Surface Elevation
 - 10/26/21
 - 10/5/21



Page 4 of 11

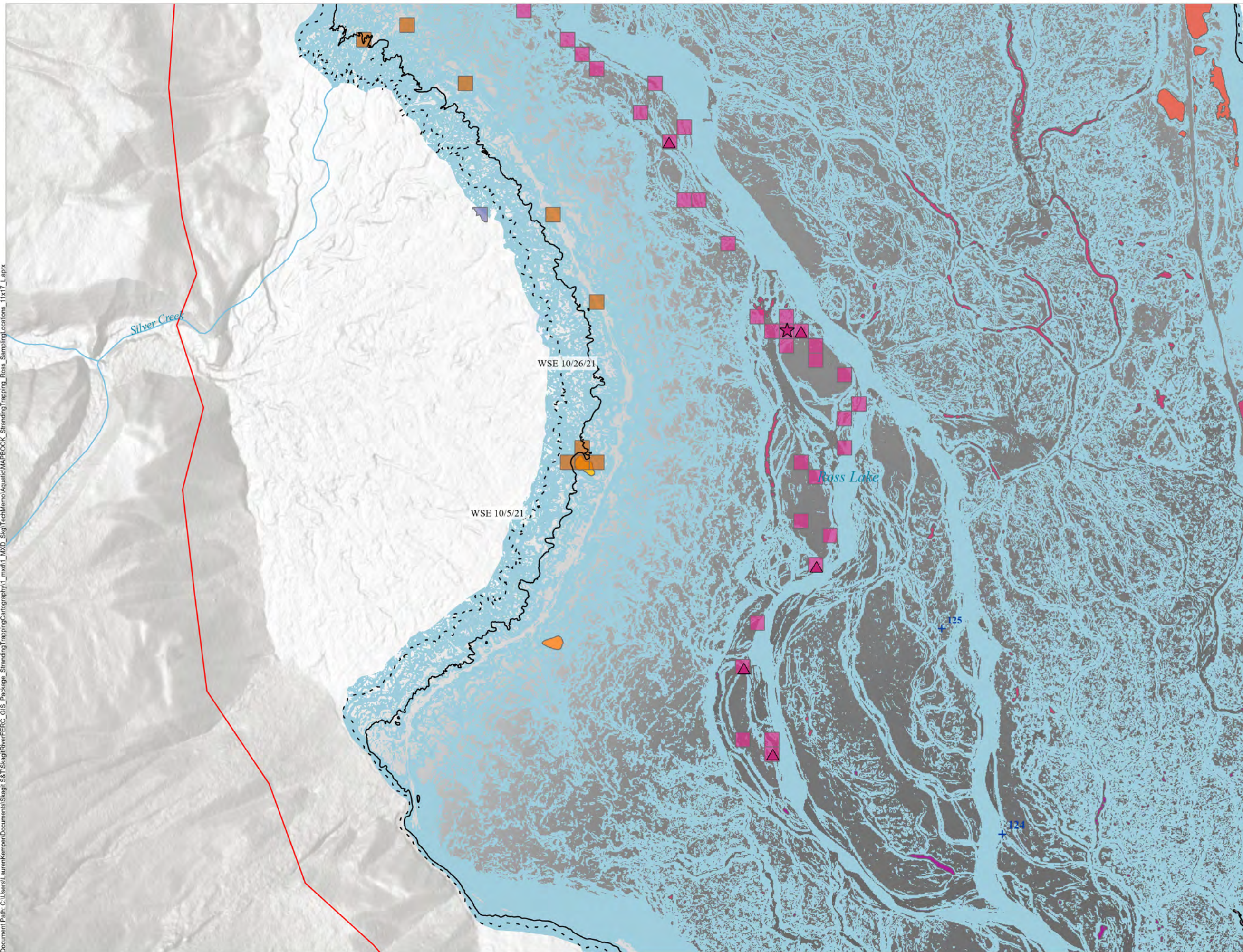


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FA-03 S&T RISK ASSESSMENT
FIGURE A-1E
ROSS LAKE: SILVER CREEK
SAMPLING LOCATIONS

FERC Project Boundary
+ Project River Miles (PRM)

Sink Elevation (ft NAVD 88)

1494 - 1506
1506 - 1519
1519 - 1532
1532 - 1545
1545 - 1558
1558 - 1570
1570 - 1583
1583 - 1596
1596 - 1609

Low Slope Elevation (ft NAVD 88)

1609
1493

Sampling Location

10/5/21
10/27/21
4/7/22

Potential S&T Zone

4/7/22

Observed S&T Fish

4/7/22

Water Surface Elevation

10/26/21
10/5/21
4/6/22

0 300 600 Feet

Page 5 of 11

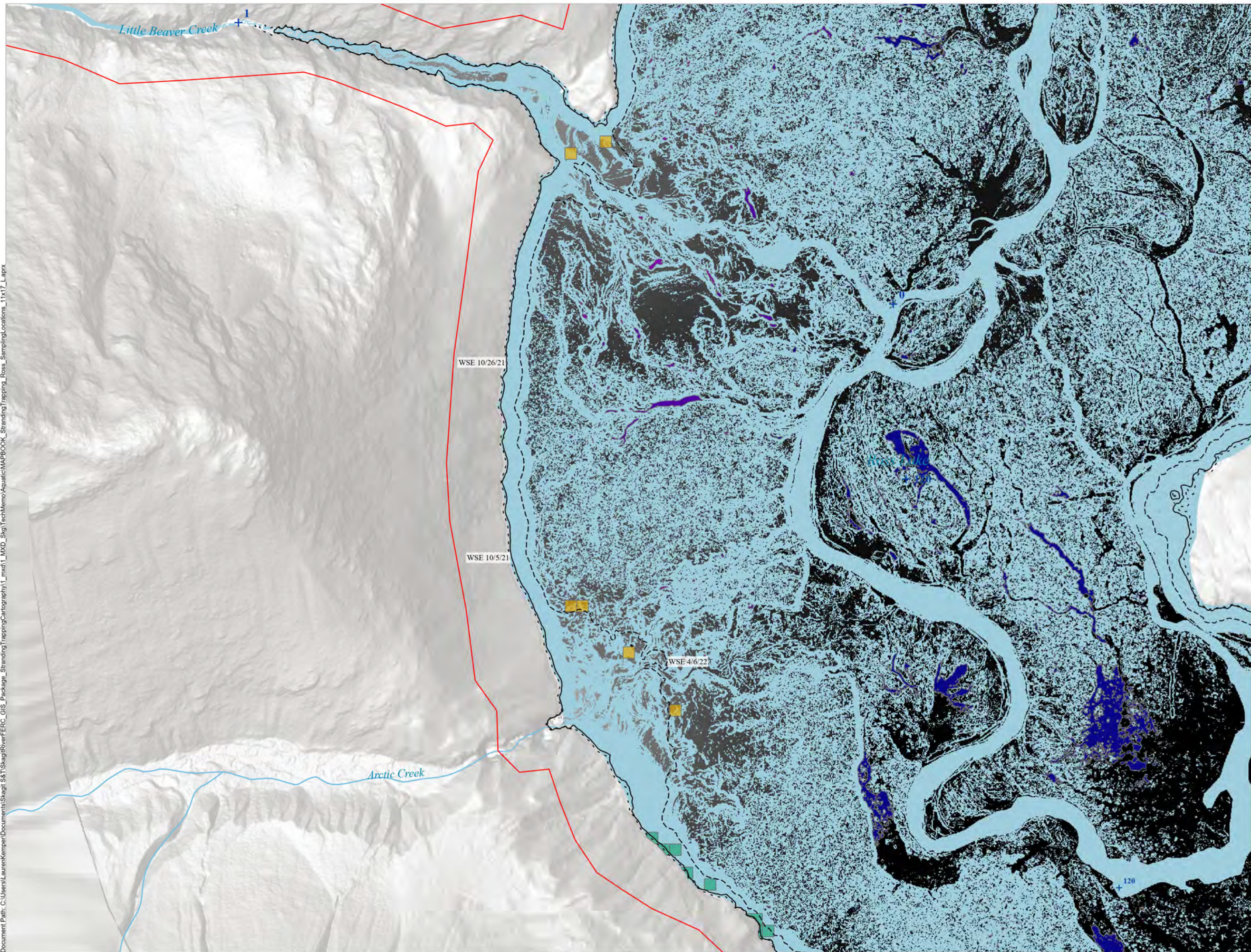
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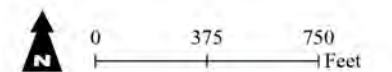
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FA-03 S&T RISK ASSESSMENT
FIGURE A-1F
ROSS LAKE: ARCTIC CREEK /
LITTLE BEAVER CREEK
SAMPLING LOCATIONS

- FERC Project Boundary
- Project River Miles (PRM)
- Sink Elevation (ft NAVD 88)
 - 1494 - 1506
 - 1506 - 1519
 - 1519 - 1532
 - 1532 - 1545
 - 1545 - 1558
 - 1558 - 1570
 - 1570 - 1583
 - 1583 - 1596
 - 1596 - 1609
- Low Slope Elevation (ft NAVD 88)
 - 1609
 - 1493
- Sampling Location
 - 10/26/21
 - 4/6/22
- Water Surface Elevation
 - 10/26/21
 - 10/5/21
 - 4/6/22



Page 6 of 11

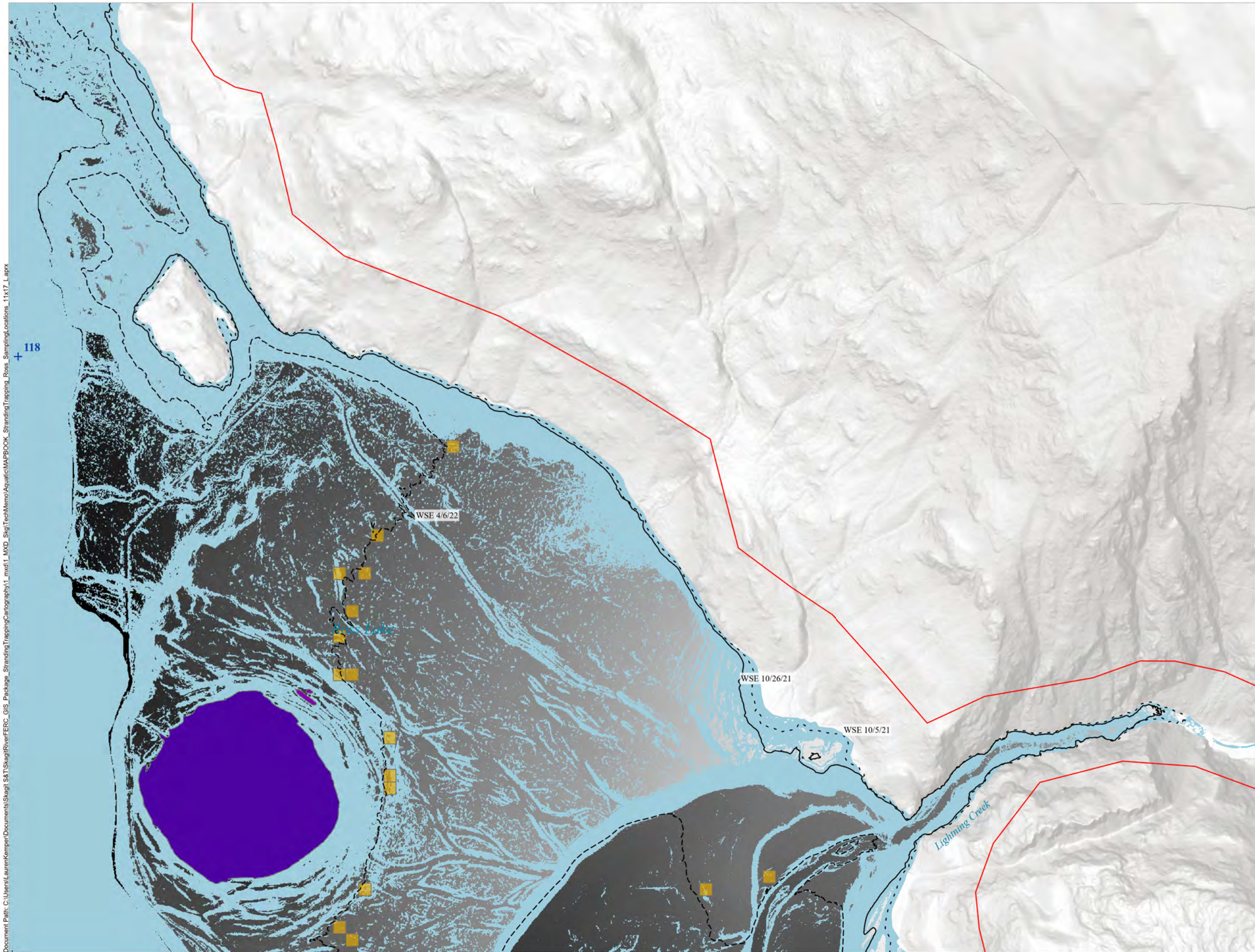


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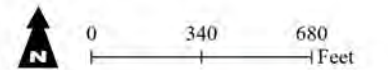
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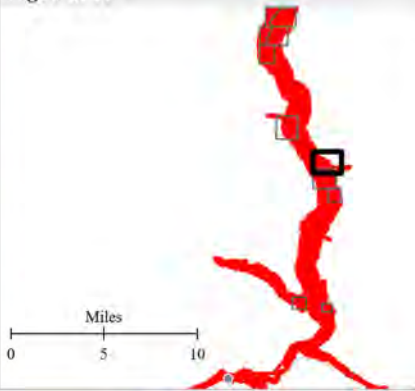


FA-03 S&T RISK ASSESSMENT
FIGURE A-1G.1
**ROSS LAKE: LOST LAKE/
LIGHTNING CREEK**
SAMPLING LOCATIONS

- FERC Project Boundary
- Project River Miles (PRM)
- Sink Elevation (ft NAVD 88)
 - 1494 - 1506
 - 1506 - 1519
 - 1519 - 1532
 - 1532 - 1545
 - 1545 - 1558
 - 1558 - 1570
 - 1570 - 1583
 - 1583 - 1596
 - 1596 - 1609
- Low Slope Elevation (ft NAVD 88)
 - 1609
 - 1493
- Sampling Location
 - 4/6/22
- Water Surface Elevation
 - 10/26/21
 - 10/5/21
 - 4/6/22



Page 7 of 11

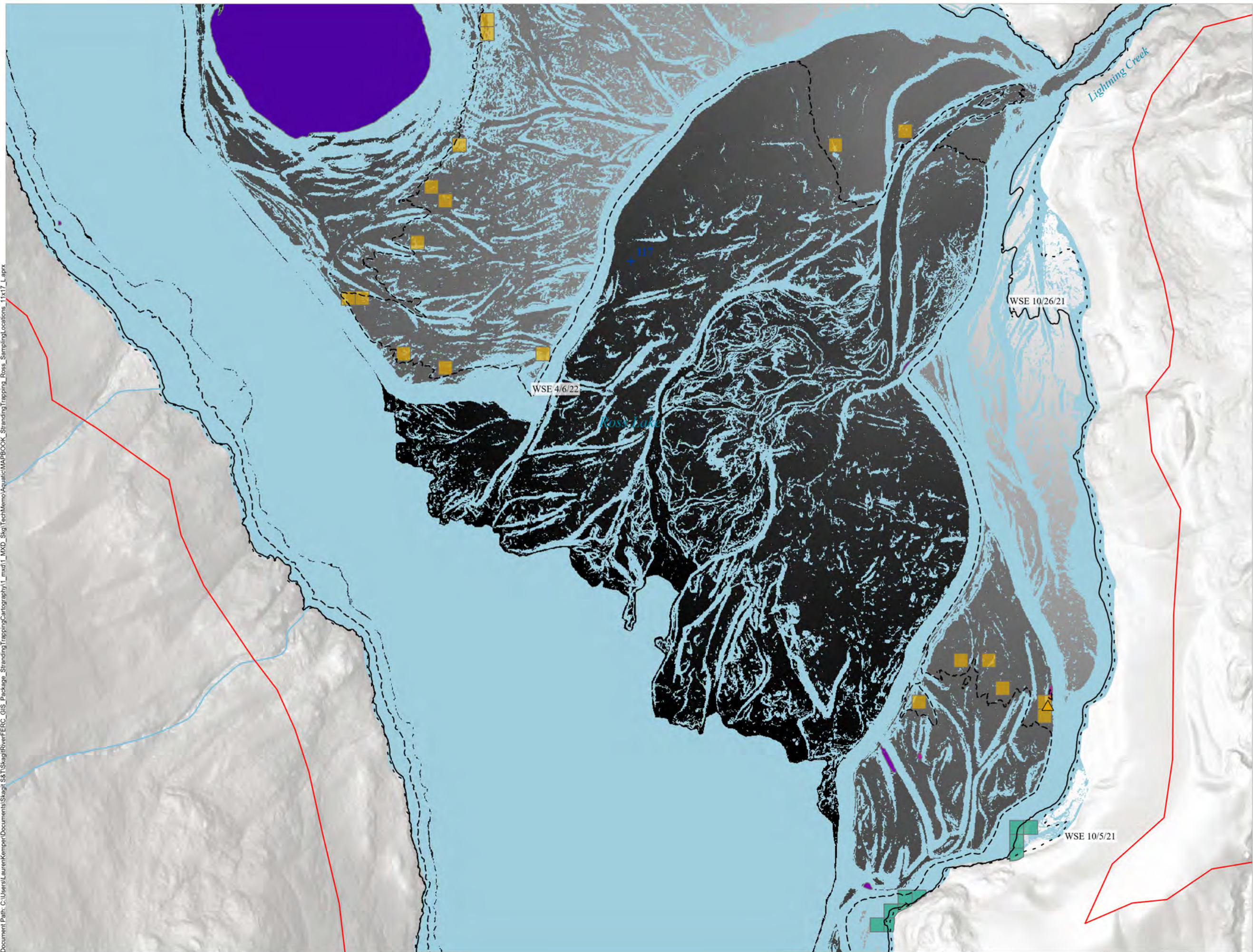


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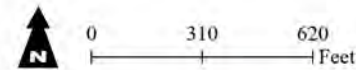
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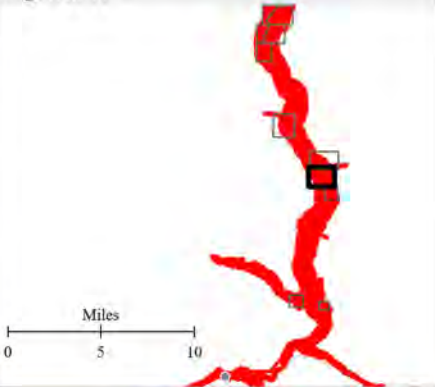


FA-03 S&T RISK ASSESSMENT
FIGURE A-1G.2
**ROSS LAKE: LOST LAKE/
LIGHTNING CREEK**
SAMPLING LOCATIONS

- FERC Project Boundary
- Project River Miles (PRM)
- Sink Elevation (ft NAVD 88)
 - 1494 - 1506
 - 1506 - 1519
 - 1519 - 1532
 - 1532 - 1545
 - 1545 - 1558
 - 1558 - 1570
 - 1570 - 1583
 - 1583 - 1596
 - 1596 - 1609
- Low Slope Elevation (ft NAVD 88)
 - 1609
 - 1493
- Sampling Location
 - 10/26/21
 - 4/6/22
- Potential S&T Zone
 - 4/6/22
- Water Surface Elevation
 - 10/26/21
 - 10/5/21
 - 4/6/22



Page 8 of 11



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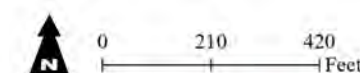
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FA-03 S&T RISK ASSESSMENT
FIGURE A-1H
ROSS LAKE: DRY CREEK
SAMPLING LOCATIONS

- FERC Project Boundary
+ Project River Miles (PRM)
Sink Elevation (ft NAVD 88)
1494 - 1506
1506 - 1519
1519 - 1532
1532 - 1545
1545 - 1558
1558 - 1570
1570 - 1583
1583 - 1596
1596 - 1609
Low Slope Elevation (ft NAVD 88)
1609
1493
Sampling Location
10/5/21
10/27/21
4/7/22
Potential S&T Zone
10/5/21
Observed S&T Fish
10/27/21
Water Surface Elevation
10/26/21
10/5/21
4/6/22



Page 9 of 11

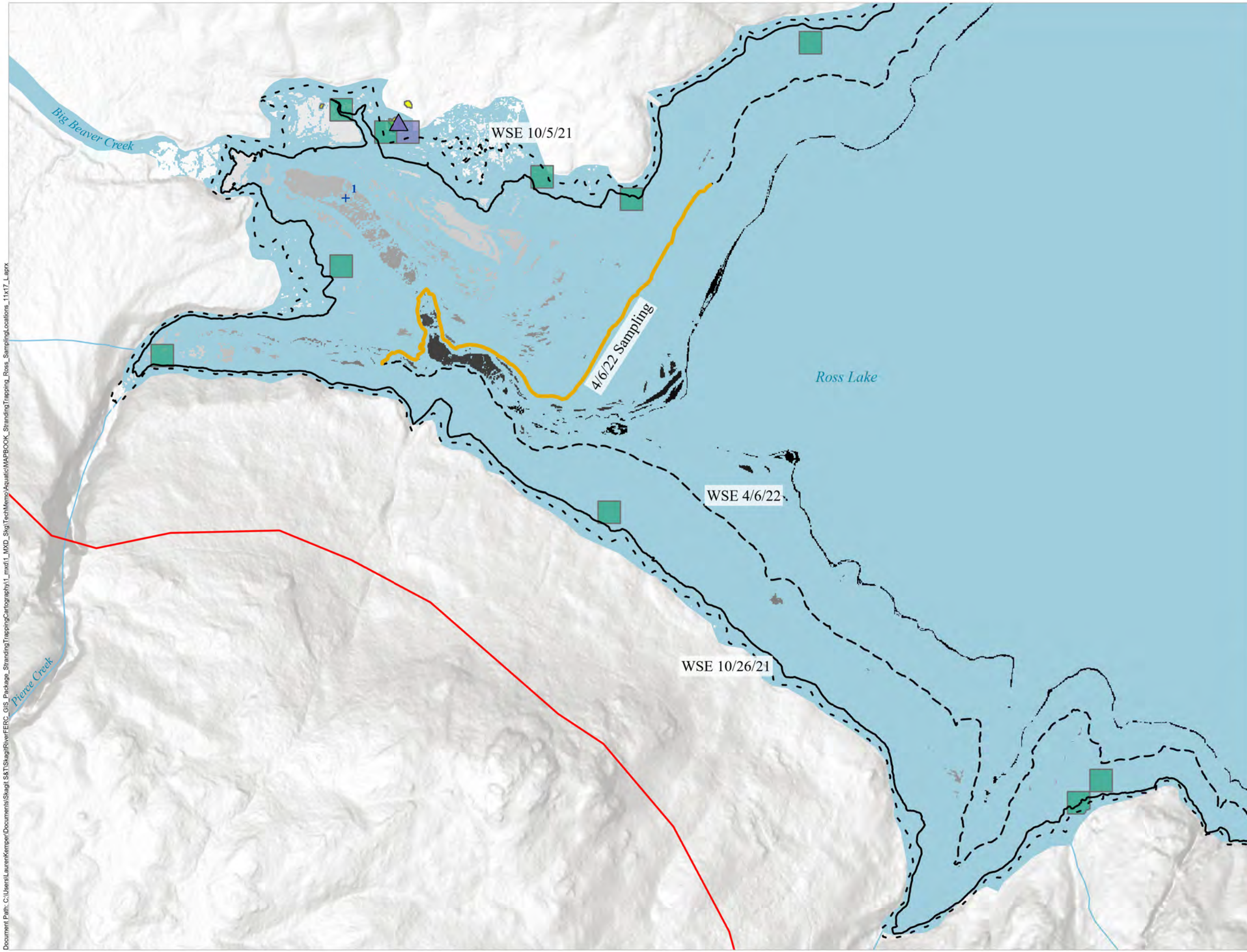


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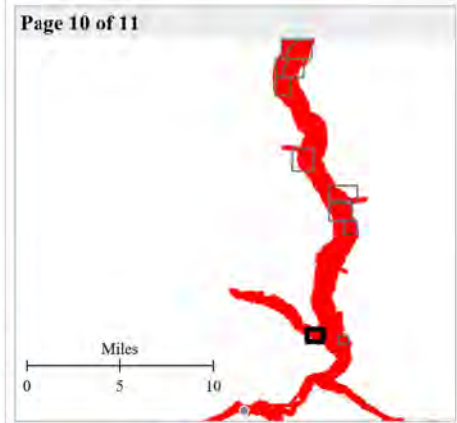
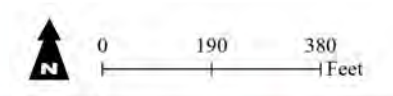
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FA-03 S&T RISK ASSESSMENT
FIGURE A-11
ROSS LAKE: BIG BEAVER
SAMPLING LOCATIONS

- FERC Project Boundary
- Project River Miles (PRM)
- Sink Elevation (ft NAVD 88)
 - 1494 - 1506
 - 1506 - 1519
 - 1519 - 1532
 - 1532 - 1545
 - 1545 - 1558
 - 1558 - 1570
 - 1570 - 1583
 - 1583 - 1596
 - 1596 - 1609
- Low Slope Elevation (ft NAVD 88)
 - 1609
 - 1493
- Sampling Location
 - 10/5/21
 - 10/26/21
 - 4/6/22 Sampling
- Potential S&T Zone
 - 10/5/21
- Water Surface Elevation
 - 10/26/21
 - 10/5/21
 - 4/6/22

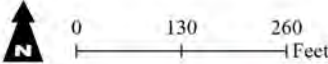


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FA-03 S&T RISK ASSESSMENT
FIGURE A-1J
ROSS LAKE: ROWLAND CREEK
SAMPLING LOCATIONS

- FERC Project Boundary
- Project River Miles (PRM)
- Sink Elevation (ft NAVD 88)
 - 1494 - 1506
 - 1506 - 1519
 - 1519 - 1532
 - 1532 - 1545
 - 1545 - 1558
 - 1558 - 1570
 - 1570 - 1583
 - 1583 - 1596
 - 1596 - 1609
- Low Slope Elevation (ft NAVD 88)
 - 1609
 - 1493
- Sampling Location
 - 10/27/21
 - 4/7/22
- Water Surface Elevation
 - 10/26/21
 - 10/5/21
 - 4/6/22



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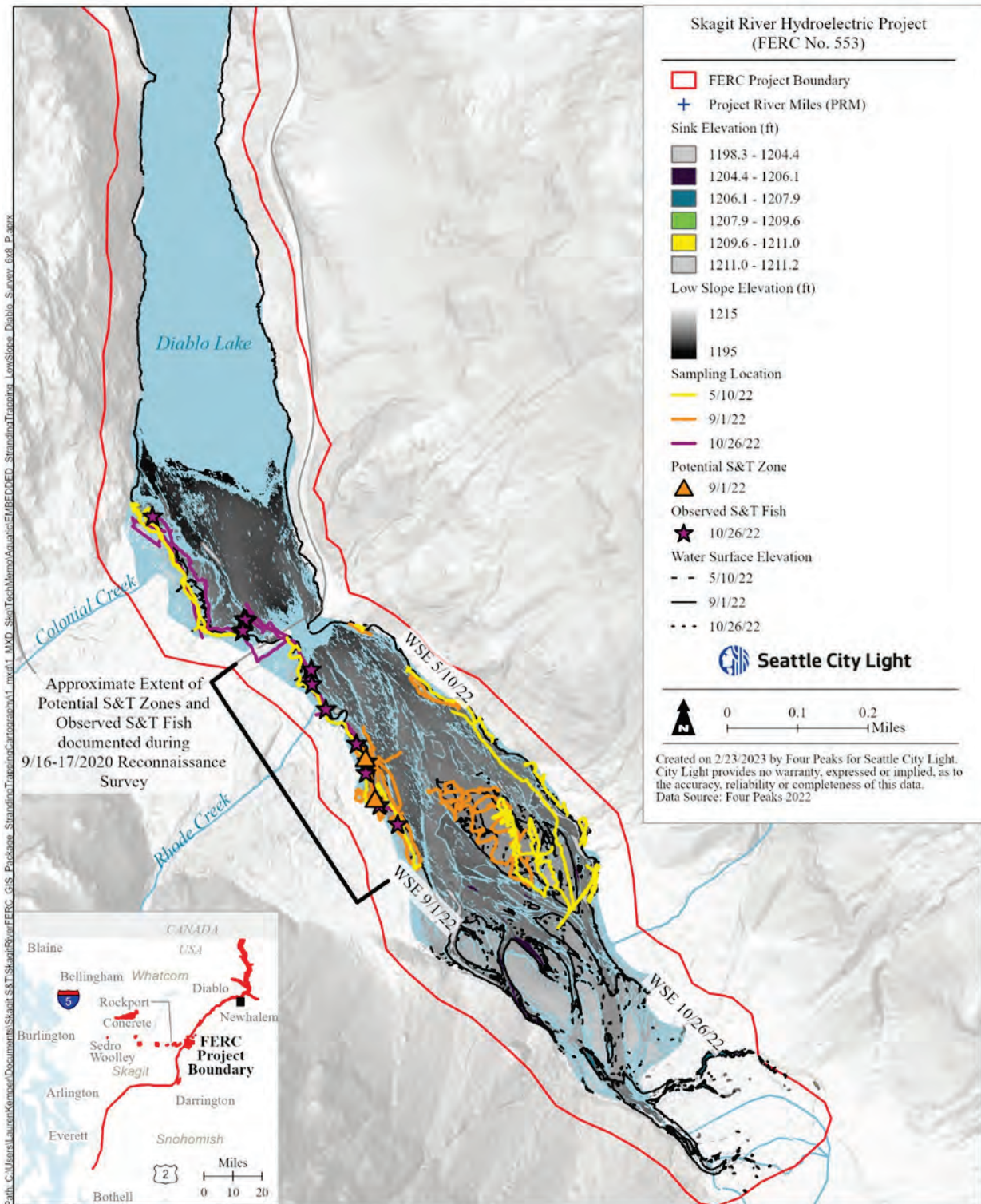
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RESERVOIR FISH STRANDING AND TRAPPING RISK ASSESSMENT

ATTACHMENT B

MAPS OF SAMPLING LOCATIONS ON DIABLO AND GORGE LAKES



Note: "Potential S&T Zone" refers to field observations of topographic features with potential to strand or trap fish. "Observed S&T Fish" refers to field observations of stranded or trapped fish, or evidence of such, including dead fish, fish remains, or predator tracks.

Figure B-1. Map of sampling locations around Diablo Lake.

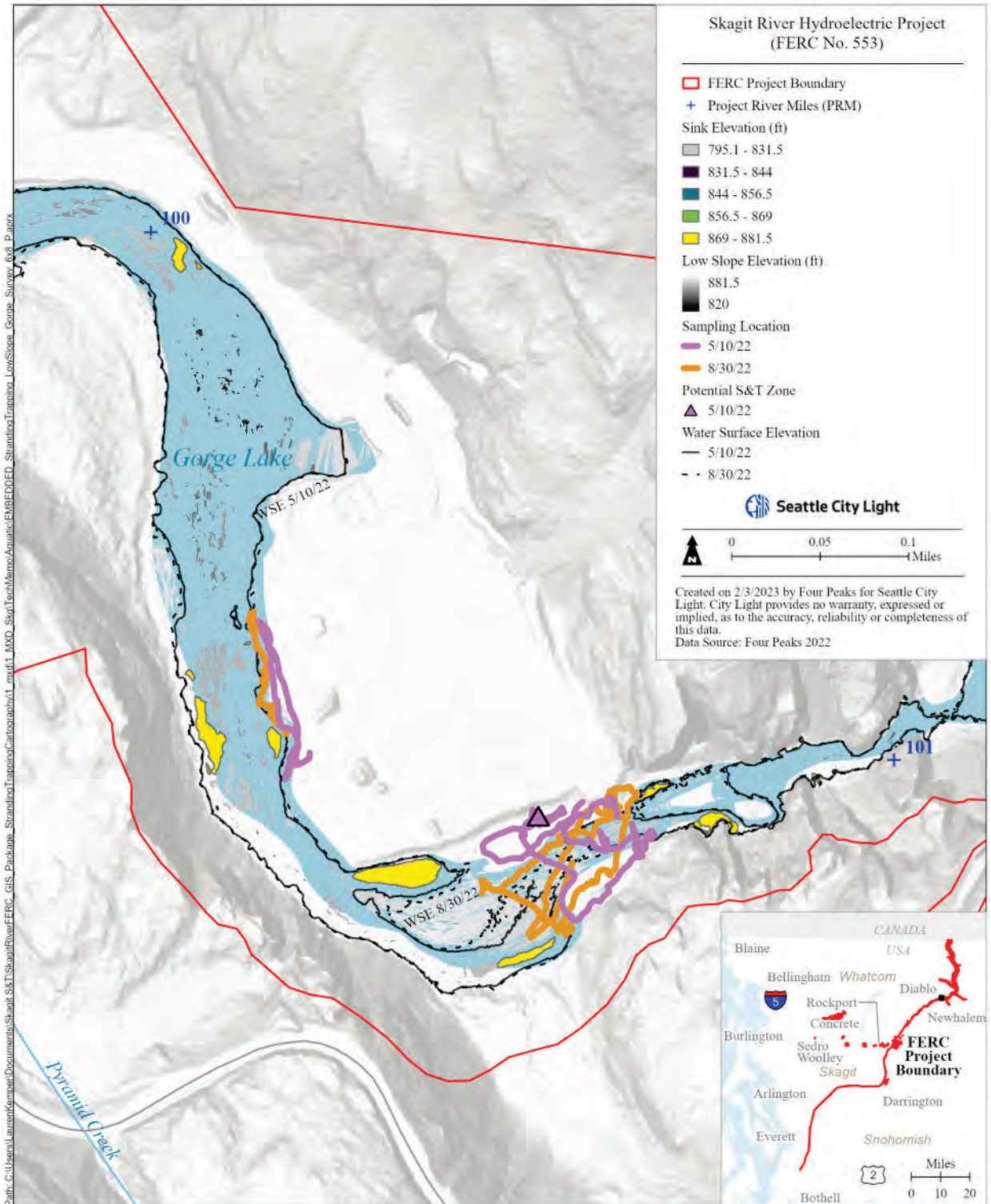


Figure B-2. Map of sampling locations and around Gorge Lake.