Eklutna Hydroelectric Project

Water Quality

Year 2 Study Report

DRAFT

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March 2023

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Terms, Acronyms, and Abbreviations

1991 Agreement	1991 Fish and Wildlife Agreement
ADEC	Alaska Department of Environmental Conservation
AWWU	Alaska Water and Wastewater Utility
°C	Celsius
cfs	cubic feet per second
DO	dissolved oxygen
ft	feet
FSP	Final Study Plans
HCP	Habitat Conservation Plan
i.e.	id est (in other words)
IIP	Initial Information Package
m	meter
mg/l	milligrams per liter
NIST	National Institute of Standards and Technology
NMFS	National Marine Fisheries Service
NTU	nephlometric turbidity units
pH	potential of hydrogen (basic or acidic scale of liquids)
PME	protection, mitigation, and enhancement
RM	river mile
SPU	Seattle Public Utilities
TP	total phosphorus
TSI	trophic state index
TSS	total suspended solids
TWG	Technical Working Group
USACE	United States Army Corps of Engineers
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
WQS	water quality station

1. INTRODUCTION

The 1991 Fish and Wildlife Agreement (1991 Agreement) was executed amongst the Municipality of Anchorage, Chugach Electric Association, Inc., Matanuska Electric Association, Inc. (collectively "Project Owners"), U.S. Fish and Wildlife Service (USFWS), National Marine Fisheries Service (NMFS), and the State of Alaska as part of the sale of the Eklutna Hydroelectric Project (Project) from the Federal government to the now Project Owners. The 1991 Agreement requires that the Project Owners conduct studies that examine and quantify, if possible, the impacts to fish and wildlife from the Project. The studies must also examine and develop protection, mitigation, and enhancement (PME) measures for fish and wildlife affected by such hydroelectric development. This examination shall consider the impact of fish and wildlife measures on other resources, including water quality, as well as available means to mitigate these impacts. The Project Owners initiated consultation in 2019 and have implemented studies to inform the development of the future Fish and Wildlife Program for the Project. As part of these studies, the Project Owners contracted McMillen Inc. to describe and evaluate water quality in the Project area.

As a requirement of the 1991 Fish and Wildlife Agreement, a comprehensive study program was conducted to assess the biological community, water quality, instream flow-fish habitat relationships, and geomorphological processes within the Eklutna River. Quantitative assessment of certain water quality parameters in Eklutna Lake and at select Eklutna River locations is an important component to assist with evaluating the effectiveness of potential future flow releases and other aquatic habitat improvement measures.

As summarized in the Initial Information Package (IIP), the water quality of Eklutna Lake and the Eklutna River is excellent, with very low concentrations of nutrients, trace metals, and other major ions. Biologically important parameters such as turbidity, temperature, dissolved oxygen (DO), and pH have been within standards established by the Alaska Department of Environmental Conservation (ADEC) according to available water quality data. However, available water quality data presented in the IIP was nearly 40 years old (APA 1984 and R&M 1985), with some of the United States Geological Survey (USGS) data up to 74 years old (USGS, 1947, 1948, 1949a, 1949b, and 1973). In addition, removal of the 1929 diversion dam created a substantial sediment source that warrants this investigation and monitoring within the lower Eklutna River. Finally, a United States Army Corps of Engineers (USACE) report on the restoration potential of the Eklutna River concluded that "…physical limnology studies of Eklutna Lake suggest that the turbidity in Eklutna Lake during much of the year is not conducive to significant primary production. Low numbers and small size of the native land locked sockeye salmon (kokanee) found in the lake supports these biological assumptions" (USACE, 2011).

This Water Quality Study was initiated in 2021 in accordance with Section 3.5 of the May 2021 Final Study Plans (FSP) (McMillen Jacobs Associates 2021). As noted in the FSP, and based on early outreach efforts, the main goal of the agencies and interested parties is to find a new balance amongst the uses of water in the Eklutna River basin, including power production, potable water supply, and fish habitat. This study was developed in consultation with the Aquatics Technical Working Group (TWG) to provide updated, relevant data necessary to develop the framework for implementation of the Fish and Wildlife Agreement. This Year 2 report provides continuous or monthly instantaneous water quality data from mid-May of 2021 through early October of 2022 at two monitoring locations in Eklutna Lake and four monitoring stations within the Eklutna River. In addition, two seasons of Trophic Status Index (TSI) data based on lake productivity protocols developed by Carlson (1977) are presented to evaluate and inform conclusions stated by the USACE (2011).

2. STUDY OBJECTIVES

The goal of the Water Quality Study was to gain a better understanding of seasonal water quality parameters within Eklutna Lake and the Eklutna River in comparison to criteria established by ADEC (Table 2-1).

Table 2-1. ADEC criteria for water use category (C)*

Parameter	Criteria
Temperature	May not exceed 20°C at any time. The following maximum temperatures may not be exceeded, where applicable: Migration routes 15°C Spawning areas 13°C Rearing areas 15°C Egg & fry incubation 13°C
Dissolved Oxygen	greater than 7 mg/l
pH	6.5 to 8.5
Turbidity	May not exceed 25 NTU above natural conditions. For all lake waters, may not exceed 5 NTU above natural conditions.
**Growth and Propagation of Fish, Shellfish, Other Aquatic Life, and Wildlife*	

Data collection objectives includes:

- Collect continuous water temperature data in Eklutna River and Eklutna Lake;
- Collect continuous pH and dissolved oxygen (DO) data in the Eklutna River and *in situ* profiles of these two water quality parameters in Eklutna Lake;
- Collect total suspended solids (TSS) and turbidity samples in Eklutna River at base flows and during at least one controlled flow release event;
  Collect total phosphorus, chloropyll *a*, and Secchi depth data in Eklutna Lake to determine its trophic status.

3. STUDY AREA

3.1. Eklutna River

Water quality study site locations in the Eklutna River are depicted in Figure 3-1; a description of these locations is summarized below:

- Water Quality Station (WQS) 1 – located just above the Thunderbird Creek confluence and below the lower dam site (temperature, DO, pH, turbidity, TSS);
- WQS 2 – located above the lower dam site near the downstream end of the AWWU access road (temperature, DO, pH, turbidity, TSS);
- WQS 3 – located in the upper river downstream of alluvial fan/sediment inputs from adjacent stream banks (turbidity, TSS);
- WQS 4 – located in the upper river upstream of alluvial fan/sediment inputs from adjacent stream banks (turbidity, TSS).

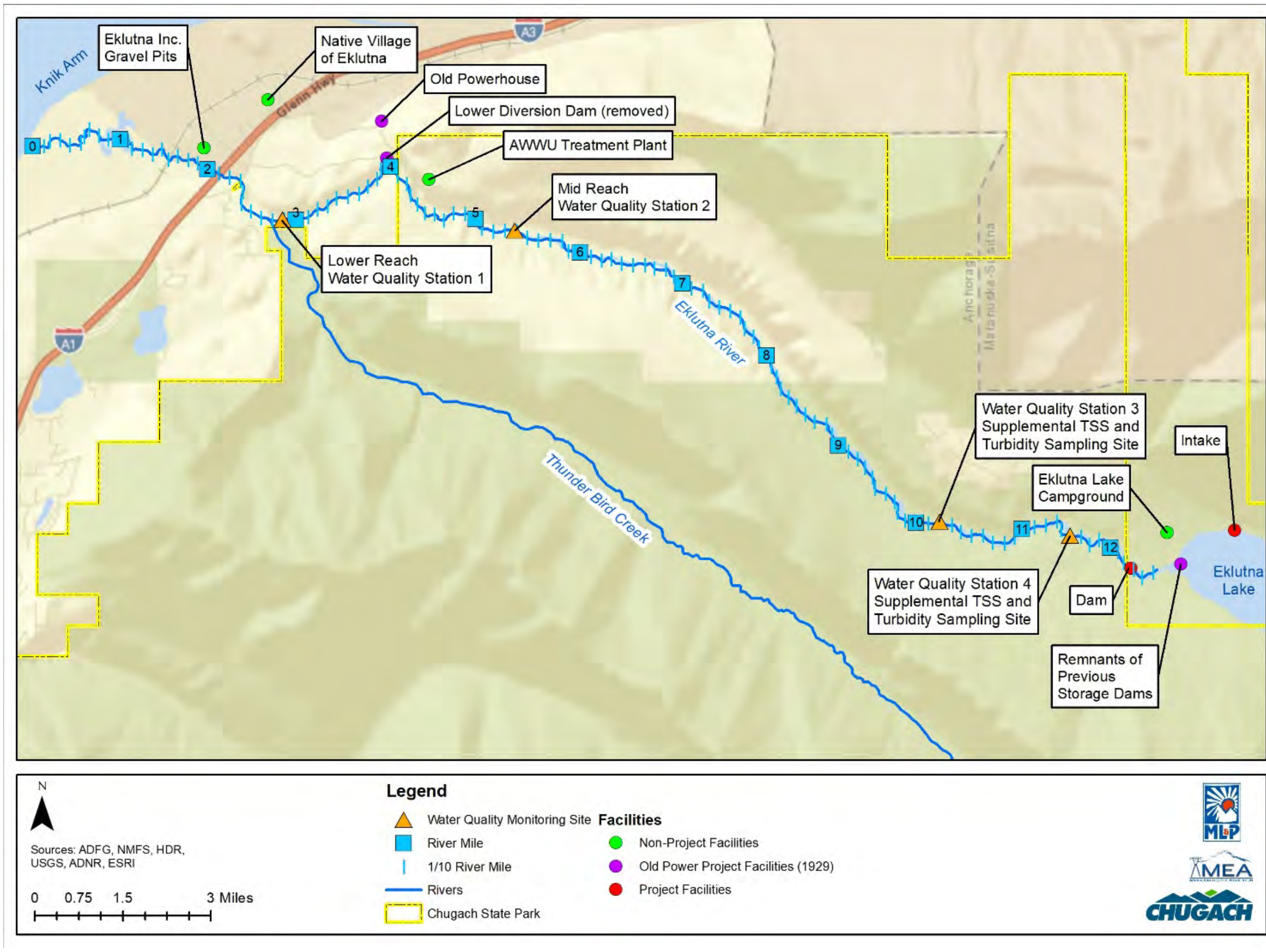

Figure 3-1. Water quality study site locations in the Eklutna River.

3.2. Eklutna Lake

Lake sampling occurred at locations where water may be released downstream into the Eklutna River. Water quality study site locations in Eklutna Lake are depicted in Figure 3-2; these locations are:

- Thermistor String 1 – located in Eklutna Lake near the Project intake structure (temperature, DO, pH, nutrients, Secchi depth)

- Thermistor String 2 – located in the pond near the Project dam in front of the spillway (temperature, DO, pH, nutrients, Secchi depth)

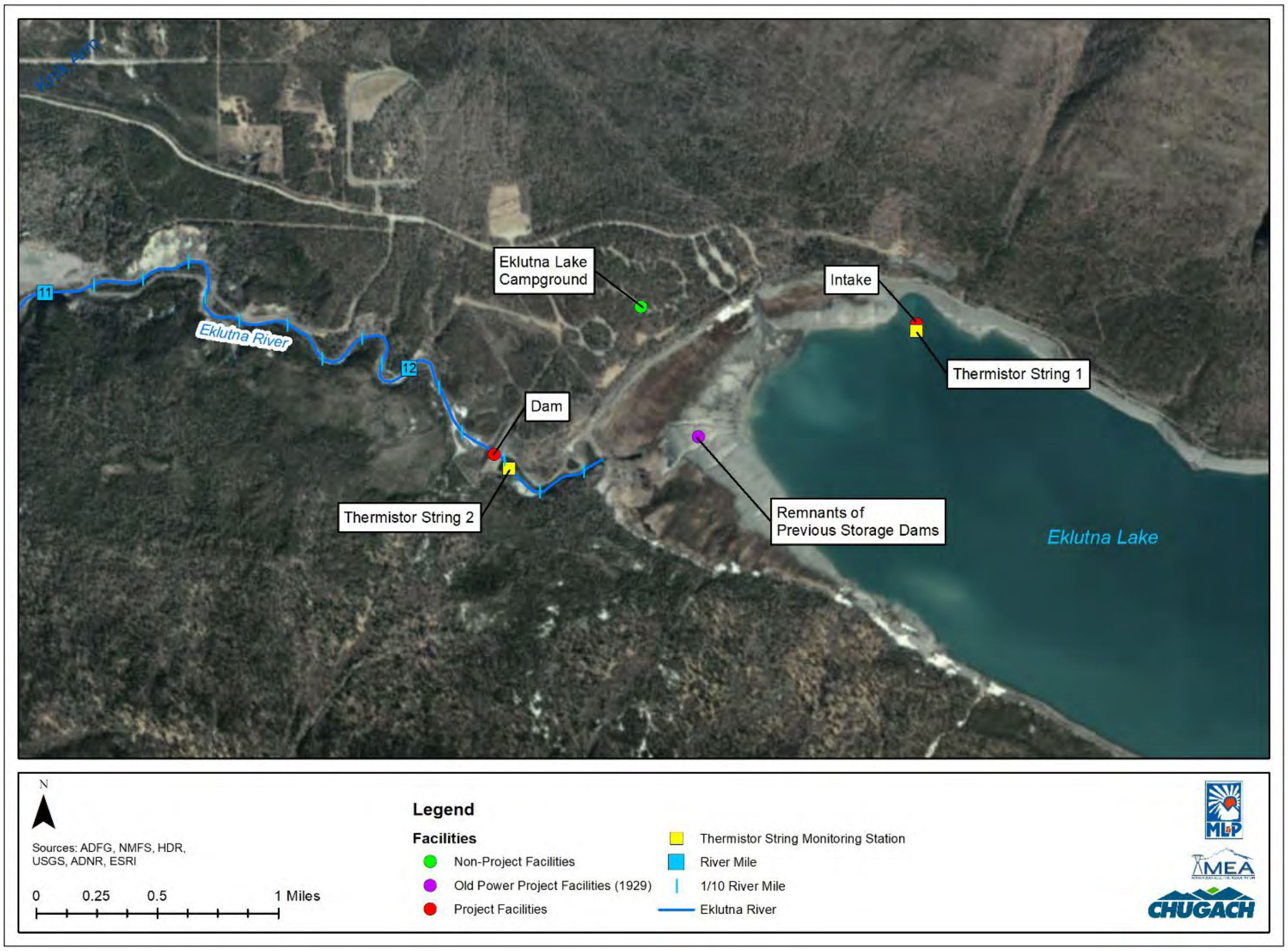

Figure 3-2. Water quality study site locations in Eklutna Lake.

4. METHODS

4.1. Water Temperature

Calibrated thermographs were utilized to continuously record water temperatures in both the Eklutna River and Eklutna Lake during the ice-free seasons of each study year from May or June through late September or mid-October. Field procedures, as well as pre-deployment instrument calibration, followed techniques detailed by Ward (2011). Following the last seasonal water quality field trip in late September of 2021, water temperature instruments remained deployed to provide a winter temperature record.

4.1.1. Eklutna River Temperature

Water temperature was continuously monitored in the Eklutna River at WQS 1 and WQS 2 using Onset ProV2 thermographs. Loggers were installed in May of 2021, and last downloaded in mid-October of 2022. Thermographs were programmed to collect data every 30 minutes. During each of the monthly field inspections and data download efforts, *in situ* water temperature measurements were collected with a National Institute of Standards and Technology (NIST) certified thermometer to validate the accuracy of thermograph readings.

4.1.2. Eklutna Lake Temperature

A thermistor string was deployed using a buoy and anchor system at each of the two lake sites (Figure 4-1). Thermistor String 1 in Eklutna Lake was deployed on June 23, 2021 and last downloaded in August of 2022 due to high lake levels that overtopped the marker buoy and precluded retrieval for instrument downloads in September and October, while Thermistor String 2 in the pond was deployed on May 20, 2021 and last downloaded in mid-October of 2022. Continuous temperature sampling occurred at two distinct depths in the water column. For the Thermistor String 1 site near the Project intake, 30-minute temperature sampling occurred at 0.5 meters below the water surface and at a lake bottom elevation of 793.6 feet (the approximate elevation of the intake). For the Thermistor String 2 site near the existing dam in front of the spillway, 30-minute temperature sampling occurred at 0.5 meters below the water surface and at a pond bottom elevation of approximately 852 feet (the elevation of the drainage outlet gate).

Similar to the Eklutna River stations, *in situ* measurements of water temperature were taken with a calibrated water quality sonde to validate logger data during each of the monthly field maintenance and data download efforts.

4.2. Dissolved Oxygen (DO) and pH

4.2.1. Eklutna River DO and pH

Calibrated Onset U26-001 DO loggers and MX2501 pH data loggers were deployed at WQS 1 and WQS 2 in the Eklutna River during the ice-free season from June 22 – September 29, 2021 and collected data every 30 minutes. The summer sampling period was prioritized to represent the time frame when DO concentrations are typically at their lowest, in response to water temperatures being at their warmest (Allan, 1995). The continuous monitoring of DO and pH also provided an assessment of diel (i.e., 24 hour) changes in DO concentrations and pH within the Eklutna River. Per manufacturer suggestions, a spot check of DO and pH levels were measured with a calibrated water quality sonde during each monthly field maintenance and data download effort. These check measurements served as confirmation of calibration integrity during the deployment period. Following the final field calibration check and data retrieval effort on September 29, 2021, DO and pH temperature loggers were removed, signifying the completion to this component to the water quality study.

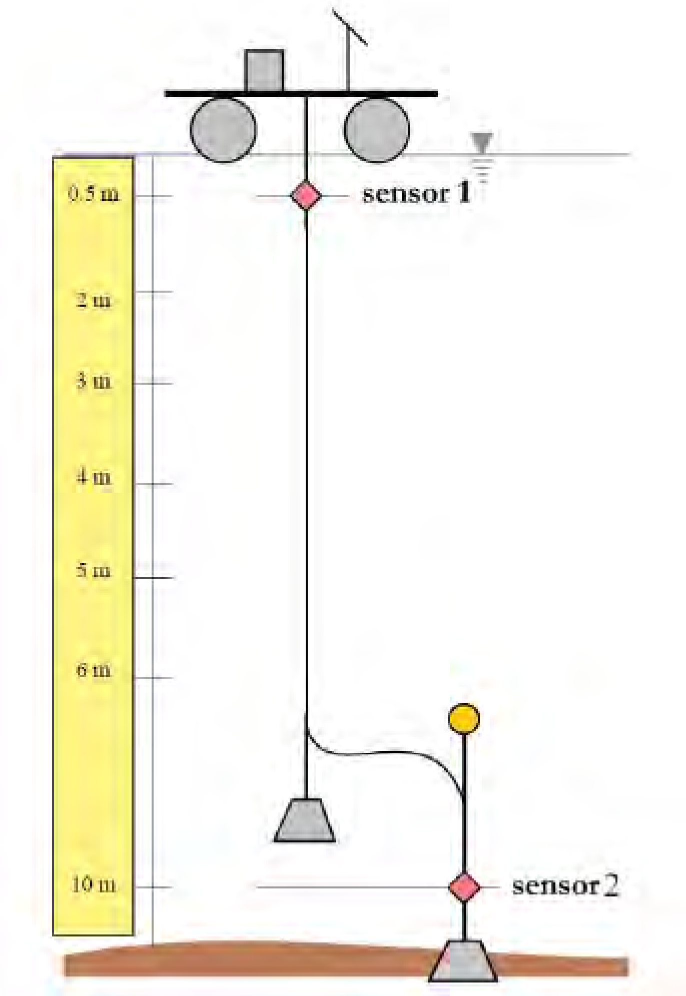

Figure 4-1. Thermistor string schematic for water temperature monitoring in Eklutna Lake.

4.2.2. Eklutna Lake DO and pH

Monthly DO and pH data were collected as *in situ* profile readings at the two lake stations. At the Thermistor String 1 location in Eklutna Lake, data were collected from June 23 to September 29, 2021, and at the Thermistor String 2 location in the pond, data were collected during the ice-free period from May 20 to September 29, 2021. DO and pH profile data were collected at 3-foot depth intervals for the entire water column utilizing a water quality sonde calibrated to manufacturer recommendations.

4.3. Eklutna Lake Trophic Status

The mid-summer lake profiling on July 14, 2021, also included the determination of Secchi depth, as well as the collection of total phosphorus and chlorophyll *a* samples. The assessment of these three lake parameters were utilized to provide an index of lake productivity or trophic status index (TSI) based on Carlson (1977). Water samples for phosphorus and chlorophyll *a* were collected near the surface of the lake and just above the lake bottom utilizing a Van Dorn sampler at the two lake monitoring sites. The Van Dorn sampler was flushed with on-site lake water prior to collection at each site and depth strata. Collected water samples for total phosphorus were transferred to pre-labeled laboratory-supplied bottles while chlorophyll *a* water samples were filtered through 0.45 µm filters and wrapped in aluminum foil. Both the phosphorus and chlorophyll *a* samples were placed immediately on ice, then delivered to analytical laboratories on the same day that the samples were collected. Total phosphorus samples were processed and analyzed by SGS Laboratories in Anchorage, AK. SGS Laboratories does not offer chlorophyll *a* analysis nor do several other Anchorage area laboratories that were contacted. Following a brief discussion with Aquatics TWG members, chlorophyll *a* concentrations were quantified by Professor Erin Larson, PhD at Alaska Pacific University. Based on the 2021 results, only the collection and analysis of chlorophyll *a* samples near the surface of Eklutna Lake and the pond were repeated on July 7, 2022 to establish a TSI range for both waterbodies.

4.4. Eklutna River Turbidity and Total Suspended Solids (TSS)

4.4.1. Eklutna River Continuous Turbidity Study

In 2021, study flow releases were conducted for the Instream Flow Study (Section 3.1 of FSP). The study flow releases started on September 13 and ended on October 6, 2021. The complete flow releases schedule is shown below.

- Monday, September 13 – Initiated flow releases at 150 cfs
- Friday, September 24 – Down-ramped to 75 cfs
- Wednesday, September 29 – Down-ramped to 25 cfs
- Wednesday, October 6 – Down-ramped to 0 cfs

Due to safety concerns from a potential mass wasting event, equipment loss, instrument battery life, and wading safety, continuous turbidity data was not monitored for 150 cfs flow release period. Turbidity monitoring was conducted the final eleven days of study flow releases. This study flow release period more accurately represented turbidity conditions under a future instream flow regime. Calibrated water quality sondes were deployed at all four water quality stations on September 27, 2021, during the 75 cfs study flow release and set to collect turbidity data every 60 minutes. Flows were down-ramped to 25 cfs on September 29, 2021, and then down-ramped to the zero-flow release condition on October 6, 2021. Continuous turbidity data collection ended approximately 24 hours after the flow releases ended on October 7, 2021.

4.4.2. Eklutna River *In-situ* Turbidity and TSS Sampling

An *in situ* assessment of turbidity and TSS was conducted at all four water quality stations in the Eklutna River. *In situ* turbidity sampling was conducted to check the accuracy of the water quality sondes, while TSS samples provided support to the Geomorphology and Sediment

Transport Study (Section 3.2 of FSP) to compare solid-phase material (i.e. sediment) being transported within the water column at each sampling station. Turbidity and TSS samples were collected as grab samples by lowering a 500 ml Nalgene bottle at mid-depth in the thalweg of the channel during the 75 cfs study flow release (September 27) and 24 hours after flow releases ended while the river was returning to base flow conditions (October 6). Collected samples were immediately stored on ice and transported to SGS Laboratories in Anchorage, AK for analysis following Standard Methods SM21 2130B and SM21 2540D for turbidity and TSS respectively (APHA 2017).

5. RESULTS

5.1. Water Temperature

5.1.1. Eklutna River Temperature

Figure 5-1 shows the time series of mean daily water temperature recorded at WQS 1 and WQS 2, the two stations where temperature was recorded. Peak water temperatures in 2021 in the Eklutna River were 9.3°C and 6.2°C at WQS 1 and WQS 2 respectively, while 2022 peak water temperatures were slightly higher at 9.7°C (WQS 1) and 7.6°C (WQS 2). Over the winter of 2021-2022 (November 1-March 31) water temperatures averaged 0.9°C and 3.3°C at WQS 1 and WQS 2 respectively, with 39 of 151 days with 0°C at WQS 1. Despite the intermittent freezing water temperatures and ice cover in the wetted channel, field observations detected flowing surface water at all times at WQS 1. Temperatures remained well above freezing during the winter at WQS 2, with a minimum temperature of 2.4°C. Water temperatures at WQS 1 were consistently higher than WQS 2 under base flows in the non-winter season (April 1-October 31). However, during the study flow releases from September 15-October 6, 2021, river temperatures increased by 3.5°C at WQS 1, 5.1°C at WQS 2 and became nearly isothermal at the two monitoring stations. Overall, the two-year monitoring period shows that both sites on the Lower Eklutna River met all ADEC temperature criteria for water use category C (Table 2-1).

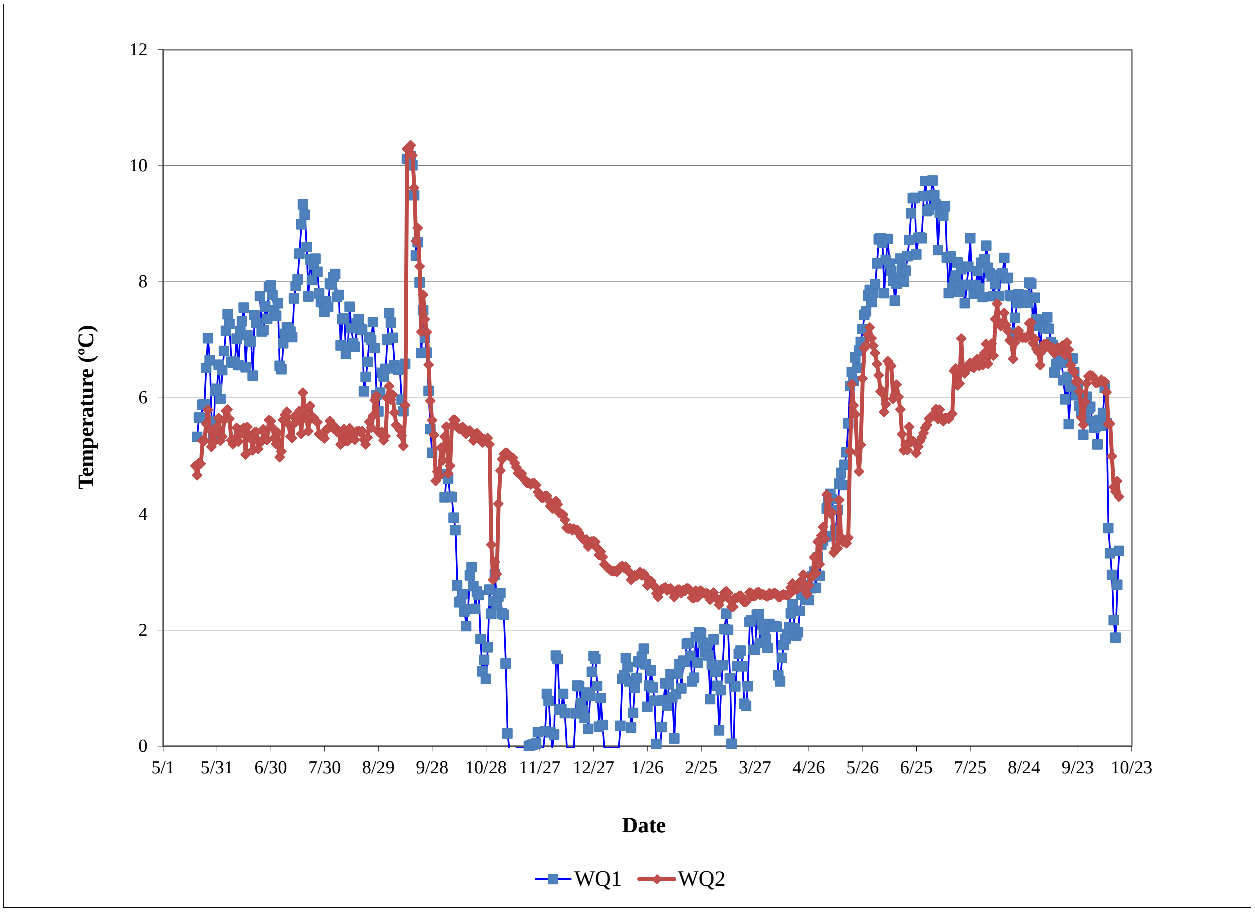

Figure 5-1. Eklutna River Water Quality Stations 1 and 2 mean daily water temperature.

5.1.2. Eklutna Lake Temperature

Figure 5-2 and Figure 5-3 show the time series of continuous mean daily water temperatures recorded at Eklutna Lake (Thermistor String 1) and the pond (Thermistor String 2), respectively. During summer seasons, surface water temperatures were higher than temperatures at depth in both Eklutna Lake and the pond, while the reverse was true during winter. Eklutna Lake mean daily surface temperature exceeded the ADEC migratory routes and rearing areas criteria of 15°C (Table 2-1) on one day during the summer of 2021 (July 19), and six days in mid-July during the summer of 2022. Mean daily temperature near the intake exceeded the ADEC criteria of 15°C on one day (July 9, 2022). Eklutna pond mean daily surface temperatures exceeded 15°C for 24 days in 2021 (July 16-August 8) but did not exceed 15°C in 2022. Near the pond outlet gate (at depth), mean daily temperature did not exceeded 15°C, but exceeded 13°C, the ADEC spawning areas and egg & fry incubation criteria (Table 2-1) for 24 days in 2021 (July 18-August 10).

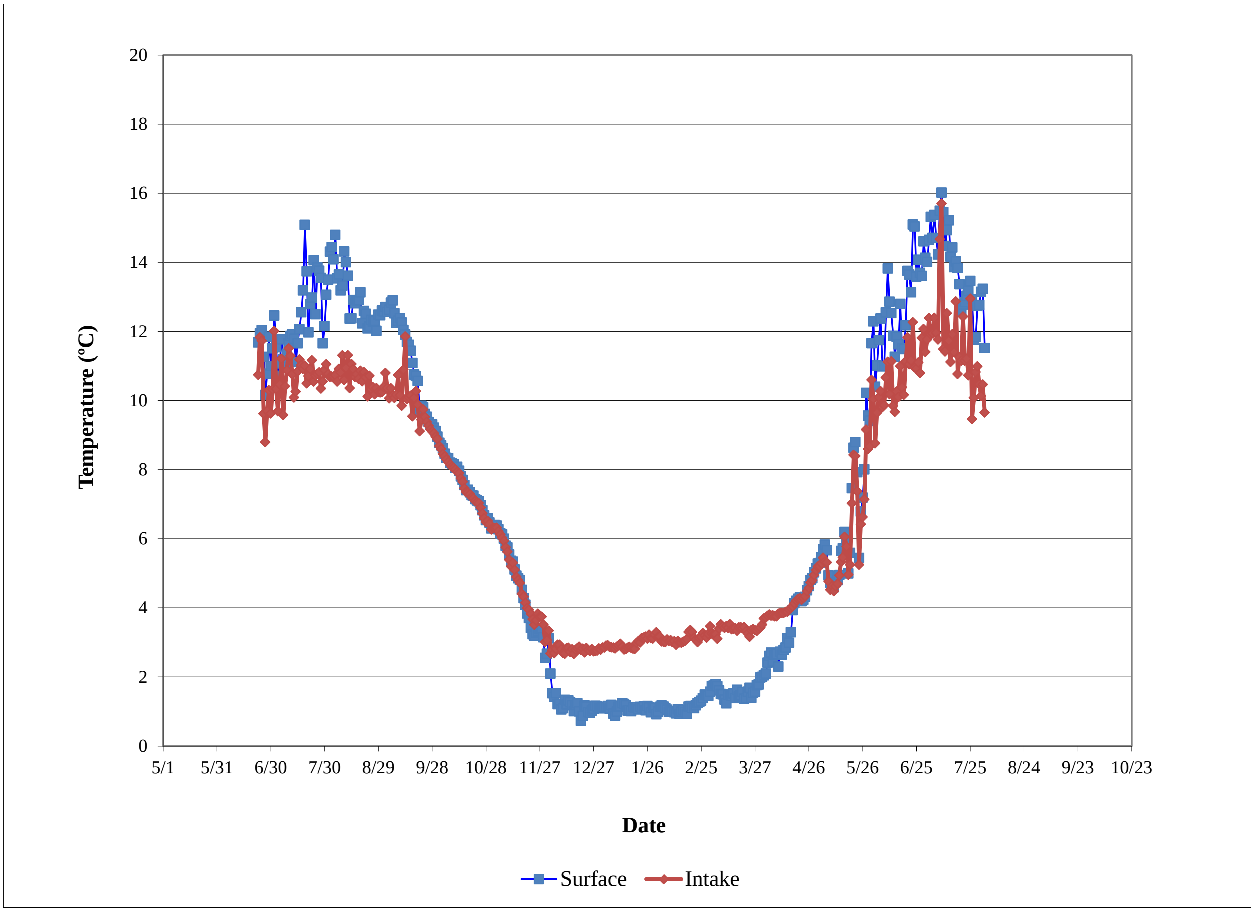

Figure 5-2. Eklutna Lake mean daily water temperature.

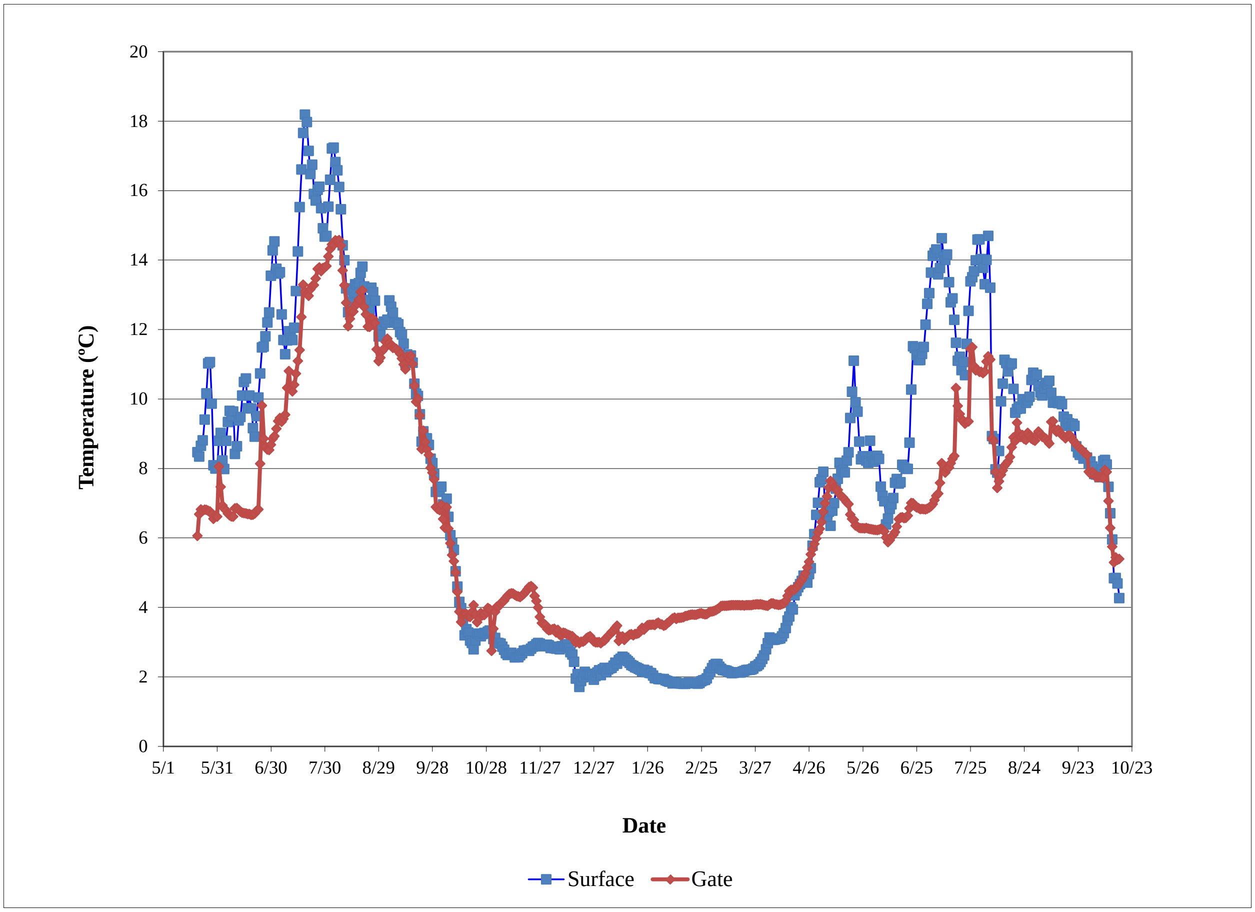

Figure 5-3. Pond mean daily water temperature.

Figure 5-4 through Figure 5-7 show water temperature profile data collected monthly at Eklutna Lake and the pond. Water temperature profiles in Eklutna Lake indicated minor stratification in mid-summer, differing by about 2°C between the surface and intake in August, and returning to a nearly isothermal condition by late September or early October. Temperature profiles in the pond followed a similar pattern, with peak temperatures at the surface and at depth occurring in August. In addition, a uniform temperature condition throughout the water column was detected by September. It interesting to note that the temperature profile on September 13, 2021, occurred during study flow releases, when Eklutna Lake and the pond were connected and Eklutna Lake water was conveyed through the pond basin. Despite this connectivity, each basin had unique temperature values, with the pond being ~1.5 C colder than Eklutna Lake.

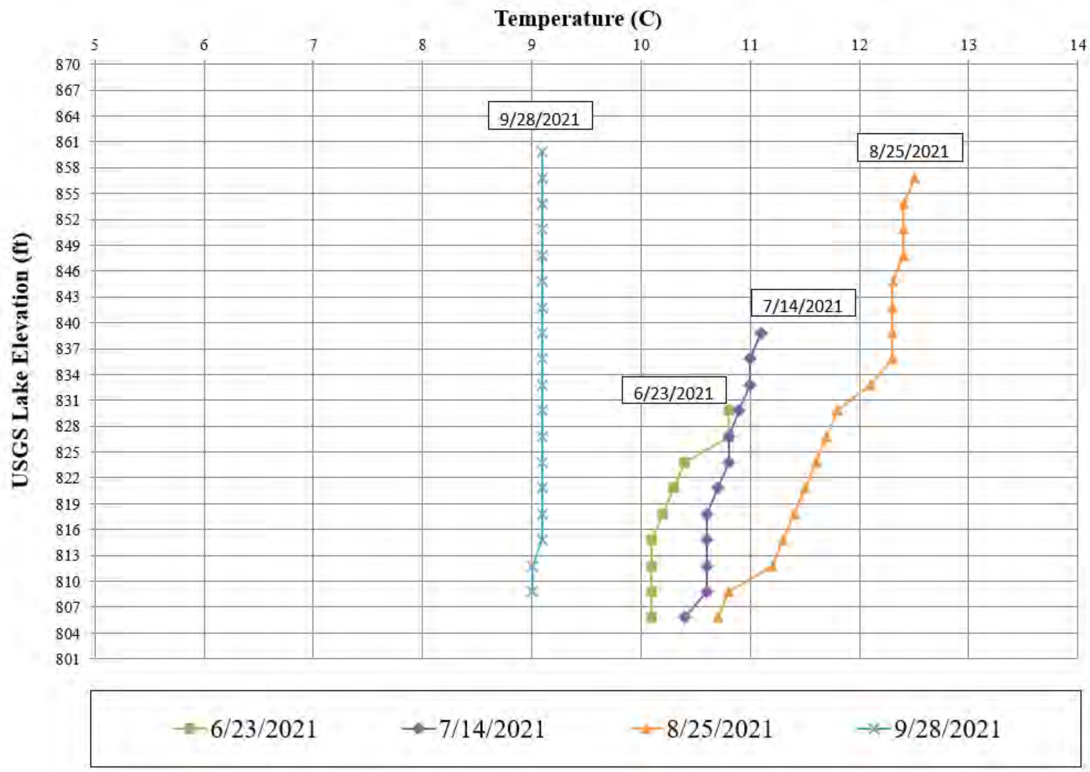

Figure 5-4. Eklutna Lake – monthly temperature profiles, 2021.

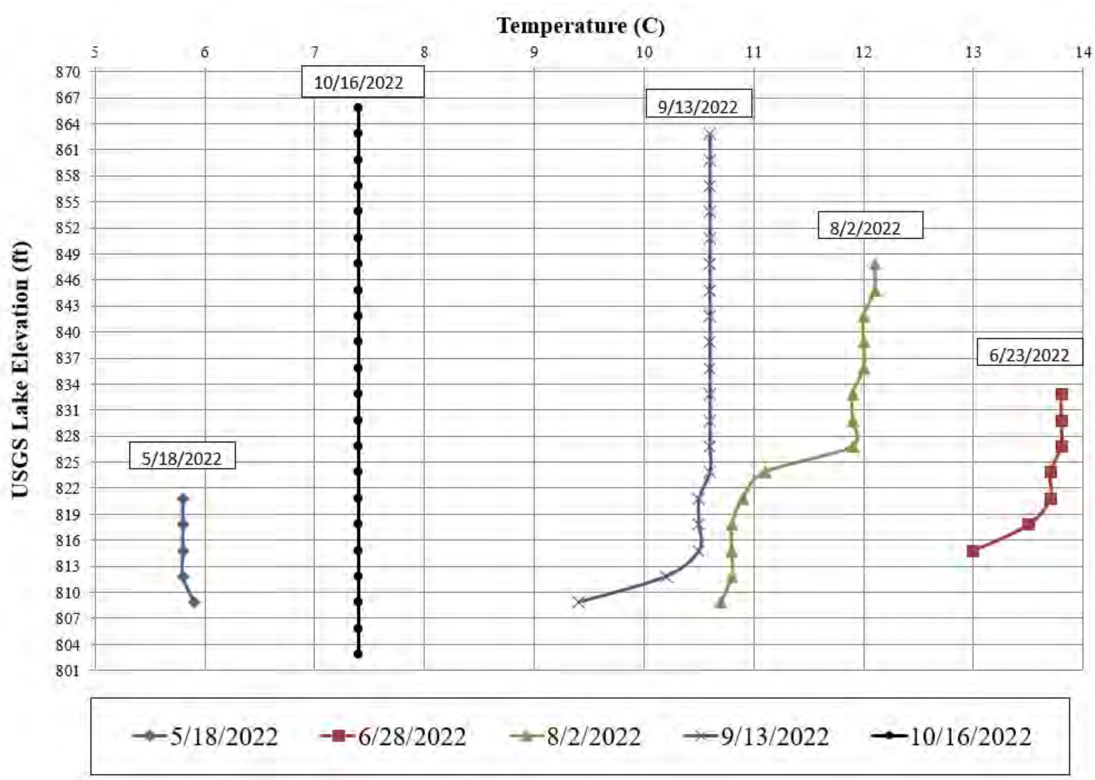

Figure 5-5. Eklutna Lake – monthly temperature profiles, 2022.

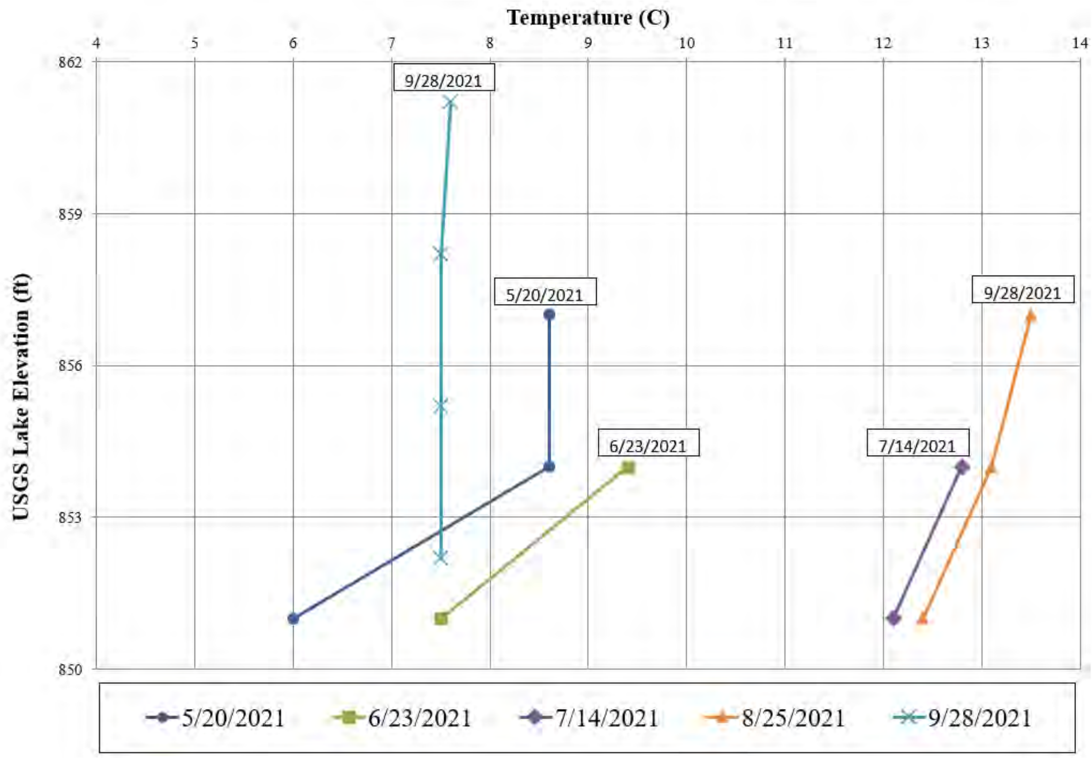

Figure 5-6. Pond - monthly water temperature profiles, 2021.

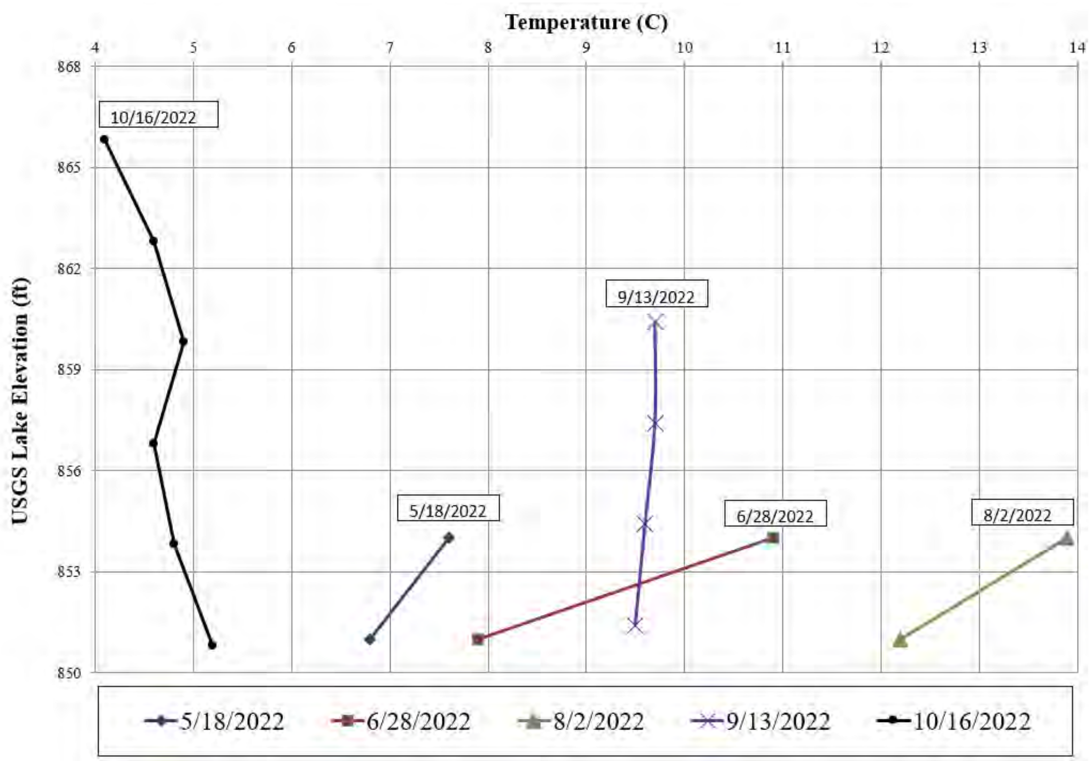

Figure 5-7. Eklutna Pond – monthly water temperature profiles, 2022.

5.2. Dissolved Oxygen (DO) and pH

5.2.1. Eklutna River DO

Figure 5-8 shows the time series of continuous DO data recorded at WQS 1 and WQS 2. DO in the Eklutna River was above 10mg/l, meeting ADEC criteria at both stations except from September 13-29, 2021, during the 150 cfs and 75 cfs study flow releases. At WQS 1, DO was lower than the ADEC fish criteria of 7mg/l for much of the 150 cfs and 75 cfs flow release period. At WQS 2, DO was lower than 7mg/l for only one day at the beginning of the 150 cfs flow release period (September 13). Given that the DO sensors rely on optical technology, it is likely these DO readings are not accurate at the high turbidity levels encountered during the study flow releases. Confirmation of erroneous data is evident in the fact that DO levels recorded during the study flow release were extremely noisy at WQS 1 and that DO concentrations returned to pre-release levels as the turbidity levels decreased.

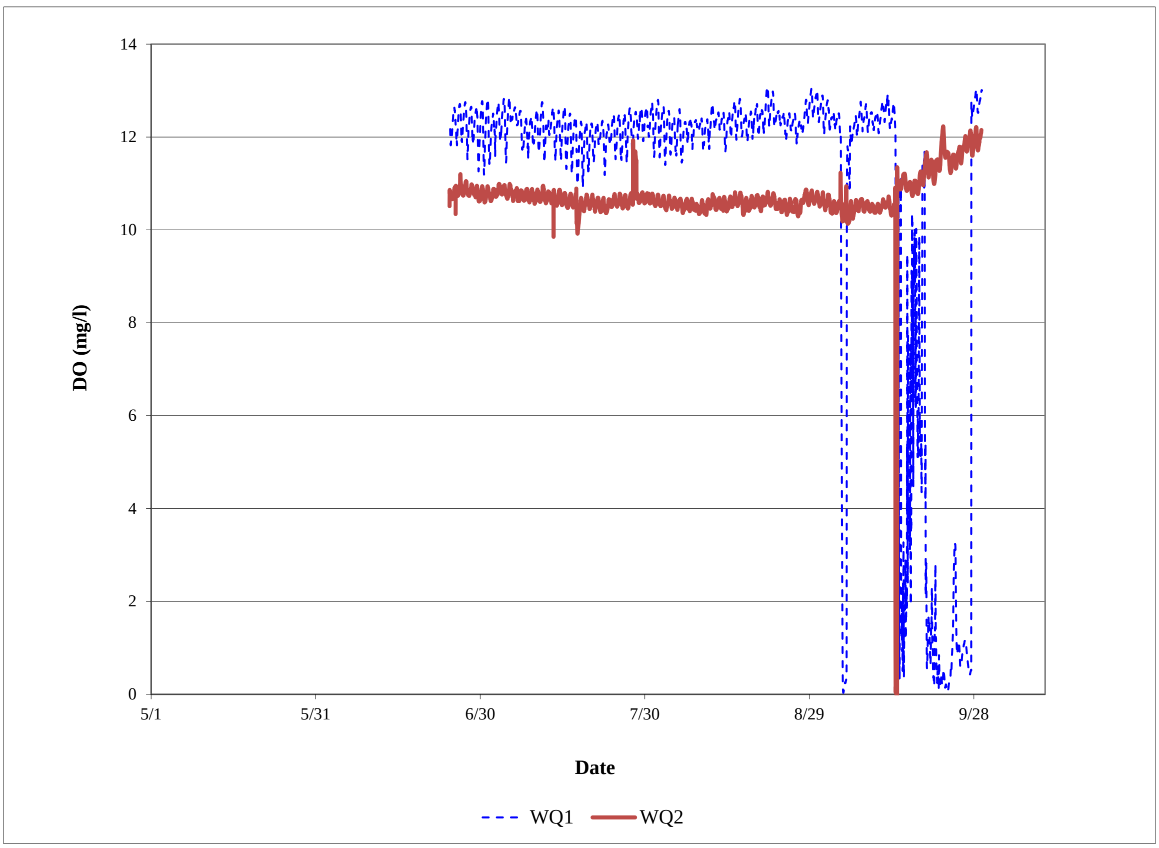

Figure 5-8. Eklutna River Water Quality Stations 1 and 2 dissolved oxygen.

5.2.2. Eklutna Lake DO

Figure 5-9 and Figure 5-10 show DO concentration and the DO saturation profile data collected monthly at Eklutna Lake. Figure 5-11 and Figure 5-12 show DO concentration and the DO saturation profile data collected monthly at the pond. DO levels in Eklutna Lake exceeded 10mg/l at all depths on all occasions that depth profiles were recorded. DO concentrations in the pond were lower than ADEC criteria of 7mg/l (Table 2-1) at the drainage outlet gate (at depth) in the spring and early summer (May 20 and June 23, 2021). DO saturation ranged from 96% to 103% in Eklutna Lake, while the pond was much more variable with DO saturation ranging from 33% to 155%. The DO profiles on September 28, 2021, occurred during study flow releases, when Eklutna Lake and the pond were connected and Eklutna Lake water was conveyed through the pond basin. During this period of connectivity, each basin had nearly identical DO concentrations of ~11.0 mg/l.

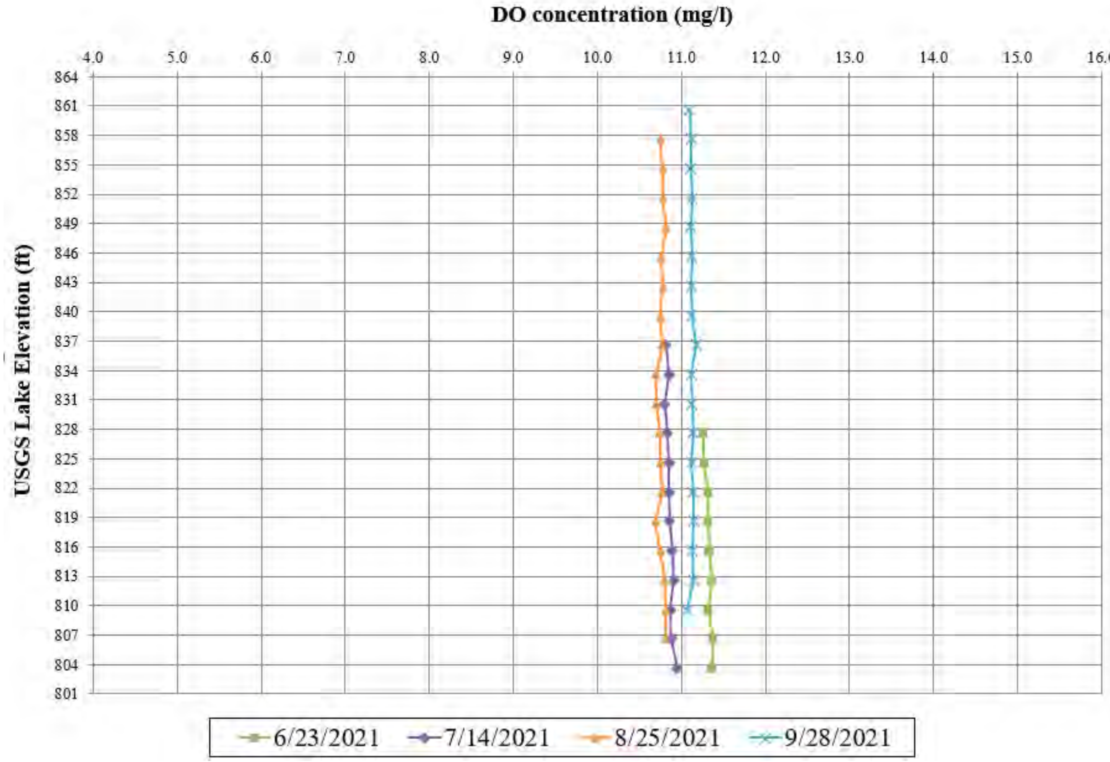

Figure 5-9. Eklutna Lake – monthly dissolved oxygen concentration profiles, 2021.

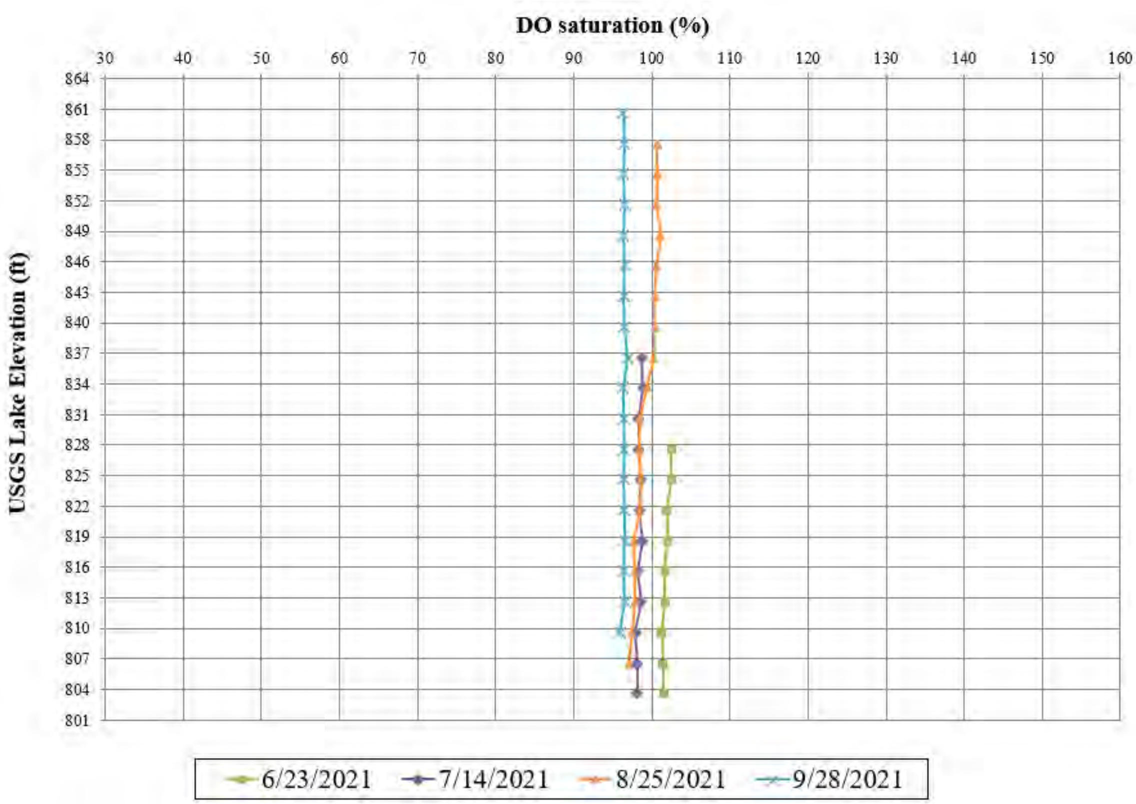

Figure 5-10. Eklutna Lake – monthly dissolved oxygen saturation profiles.

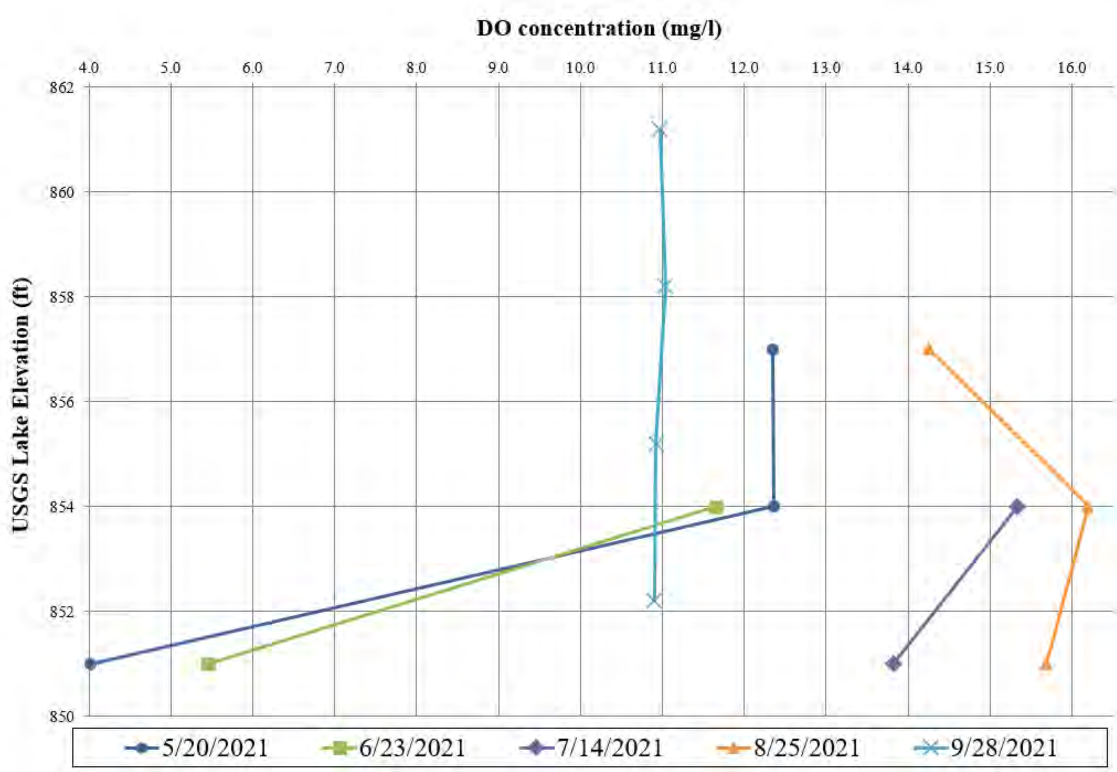

Figure 5-11. Eklutna Pond – monthly dissolved oxygen concentration profiles, 2021.

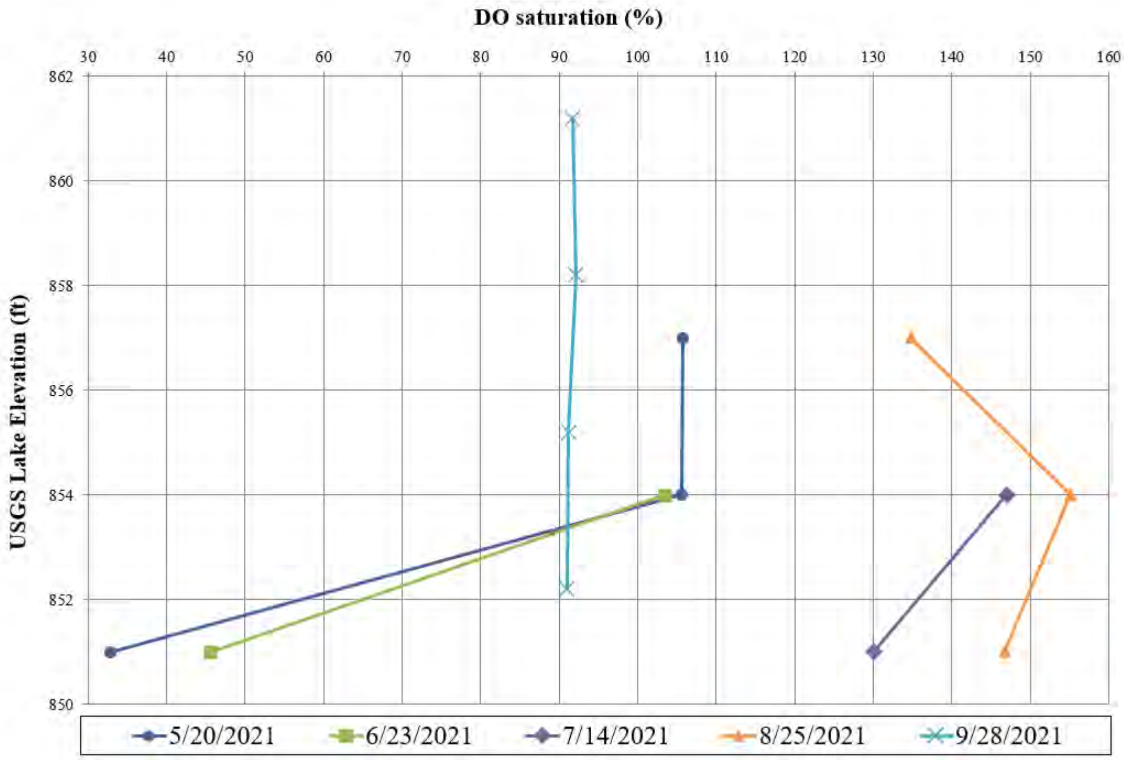

Figure 5-12. Eklutna Pond – monthly dissolved oxygen saturation profiles, 2021.

5.2.3. Eklutna River pH

Figure 5-13 shows the time series of continuous pH data recorded at WQS 1 and WQS 2. Eklutna River pH values ranged from 7.8 to a maximum of 8.6, just above the ADEC fish criteria maximum of 8.5 (Table 2-1). The pH exceedances occurred at WQS 1 intermittently from mid-July to mid-September. Readings for pH at WQS 2 did not exceed ADEC criteria. Of note, during the 150 cfs and 75 cfs study flow releases (September 13 – September 29, 2021), pH at WQS 1 noticeably decreased and held relatively steady through the end of the monitoring period on September 29, 2021.

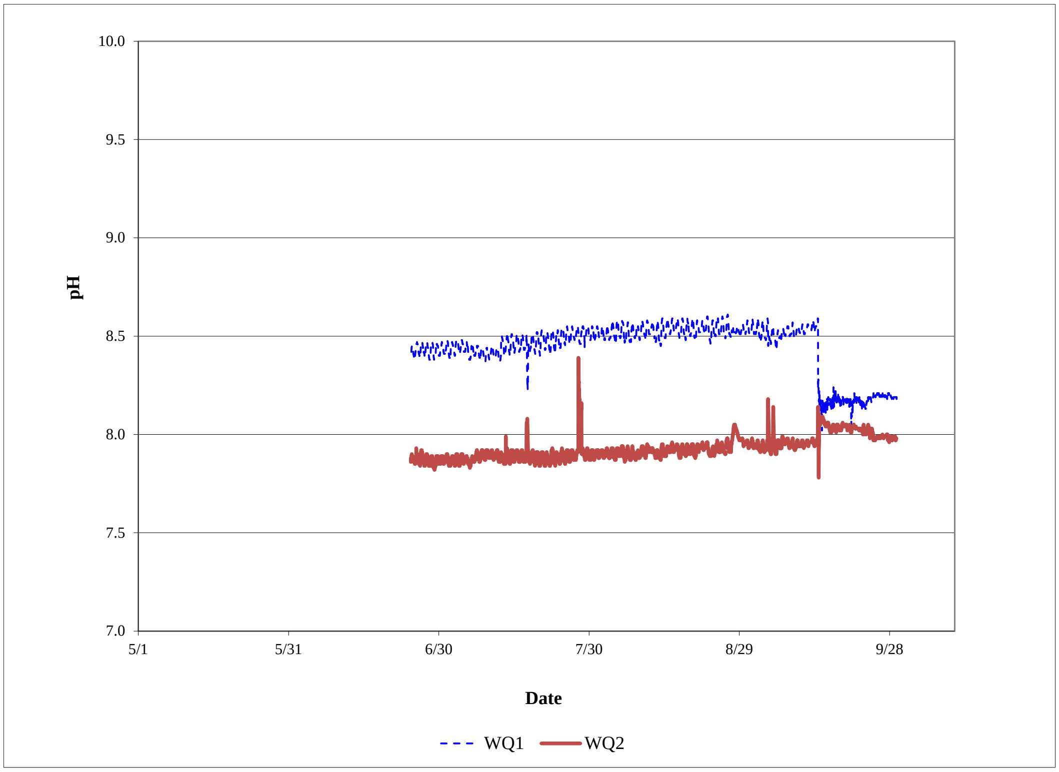

Figure 5-13. Eklutna River Water Quality Stations 1 and 2 pH.

5.2.4. Eklutna Lake pH

Figure 5-14 and Figure 5-15 show pH profile data collected monthly at Eklutna Lake (Thermistor String 1) and the pond (Thermistor String 2), respectively. In Eklutna Lake, profile measurements recorded pH levels between 7.8 and 8.4, meeting ADEC criteria of 6.5 -8.5 (Table 2-1) at all depths on all occasions. In the pond, profile measurements recorded pH levels between 7.4 and 8.5, with the exception of surface and depth measurements on July 14, 2021, and at a depth of 6 feet on August 25, 2021. On these two dates, the pH readings were close to 8.6, exceeding the ADEC criteria for fish of 8.5. Interestingly, the pH profile on September 28, 2021, occurred during study flow releases, when Eklutna Lake and the pond were connected and Eklutna Lake water was conveyed through the pond basin. Despite this connectivity, each basin had a unique pH value, with the pond having a pH of ~7.9 throughout the depth column while Eklutna Lake had a pH range of ~8.3 near the surface to ~8.1 at depth.

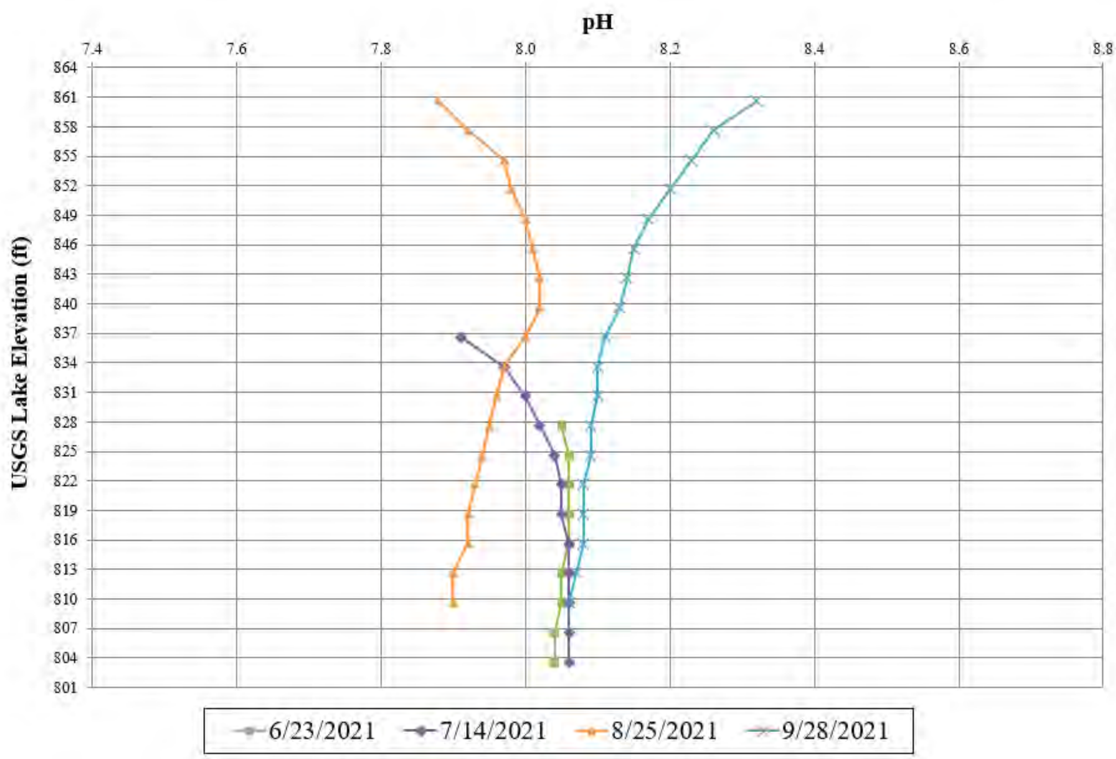

Figure 5-14. Eklutna Lake – monthly pH profiles, 2021.

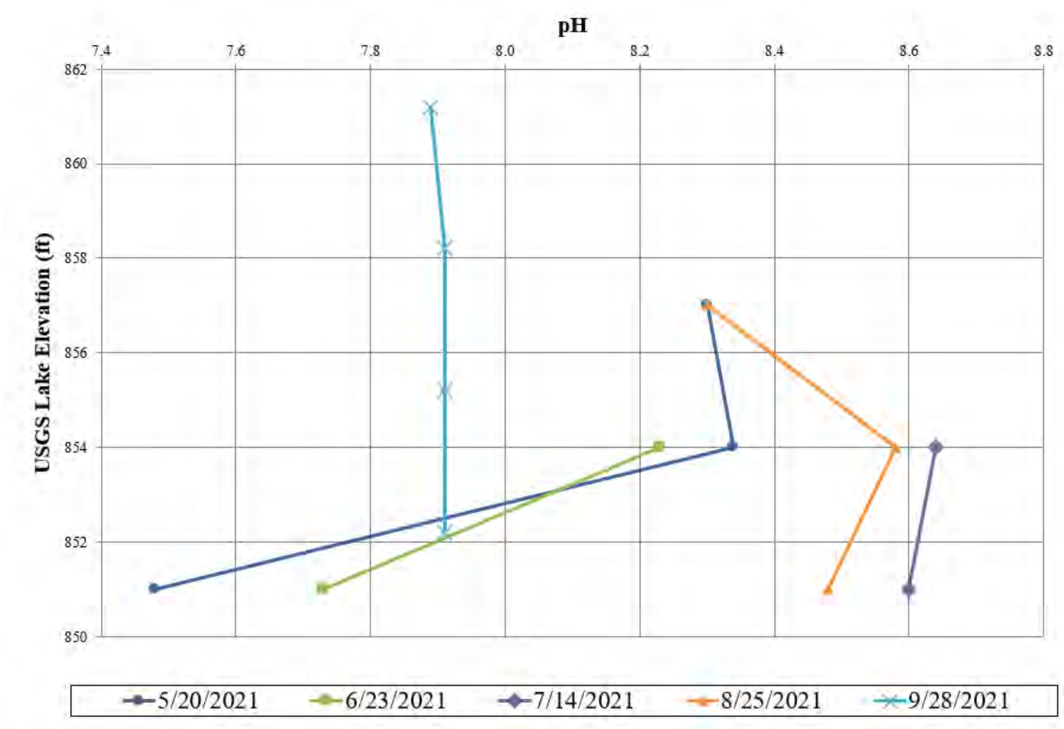

Figure 5-15. Eklutna Pond – monthly pH profiles, 2021.

5.3. Eklutna Lake Trophic Status

Table 5-1 shows analysis results from samples taken for TSI assessment in Eklutna Lake and the pond. Given that total phosphorus concentrations were below detection limits and that Secchi depths were greatly diminished by glacial turbidity, these two factors could not be utilized for the TSI calculation. Secchi depths recorded in July 2021 were 0.85 m in Eklutna Lake and 2.04 m in the pond (Table 5-1). For comparison, phosphorus concentrations and Secchi depths at other glacially-fed lakes in Alaska were examined. Secchi depth data from glacially-fed sockeye nursery lakes in the Bristol Bay region had readings ranging from 1.6m to 13.2m (Burgner, et. al., 1969). However, the Burgner, et. al. study (1969) showed that Chignik Lake had one of the shallower Secchi depths (1.9 m), but high photosynthetic activity with a chlorophyll *a* concentration of 15.3 ug/l (compared to 0.29 – 1.02 ug/l at Eklutna Lake and pond – Table 5-1), and correspondingly the second highest escapement value of the 10 lakes studied.

Based exclusively on the chlorophyll *a* concentrations, average TSI score of 18.9 and 27.0 were calculated for Eklutna Lake and the pond respectively in 2021. The TSI index for Eklutna Lake and the pond were 10.6 and 9.8, respectively in 2022. In comparison to nearby glacially-fed sockeye nursery lakes, historical limnological data from Kenai and Skilak Lakes have TSI scores of 18.8 based on average chlorophyll *a* concentrations of 0.3 ug/l for both basins (ADF&G 2003).

Table 5-1. Eklutna Lake and Pond trophic factors, July 14, 2021 and July 7, 2022.

Sample Source	Chlorophyll *a* (ug/l)	Total Phosphorus (mg/l)	Secchi Depth (m)	TSI Score*
Eklutna Lake (2021)	0.29 / 0.32	<0.04	0.85	18.9
Pond (2021)	0.47 / 1.02	<0.04	2.04	27.0
Eklutna Lake (2022)	0.13	*not collected*	*not collected*	10.6
Pond (2022)	0.12	*not collected*	*not collected*	9.8
* *Calculation Equation: TSI = 9.81* ln(CHL a) + 30.6*				

5.4. Eklutna River Turbidity and Total Suspended Solids (TSS)

Figure 5-16 shows the continuous time series turbidity data collected during the study flow releases. Table 5-2 and Table 5-3 summarize the laboratory results from grab samples taken for turbidity and TSS at the beginning and end of the continuous monitoring period (September 27 and October 6, 2021). During the 75 cfs to 25 cfs study flow releases, both turbidity and TSS increased moving downstream, with a peak turbidity value and TSS concentration in excess of 250 NTU and 146 mg/L respectively. At stations WQ1 and WQ2 turbidity was 108 NTU and 41 NTU above natural conditions, respectively, while the upper valley sites WQ3 and WQ4 increase by no more than 2.1 NTU. Stations WQ1 and WQ2 were well above the 25 NTU criteria established by ADEC[1] (Table 2-1) and correspond directly to each monitoring station's proximity to unconsolidated sediment sources.

[1] Note: There is not a TSS criteria.

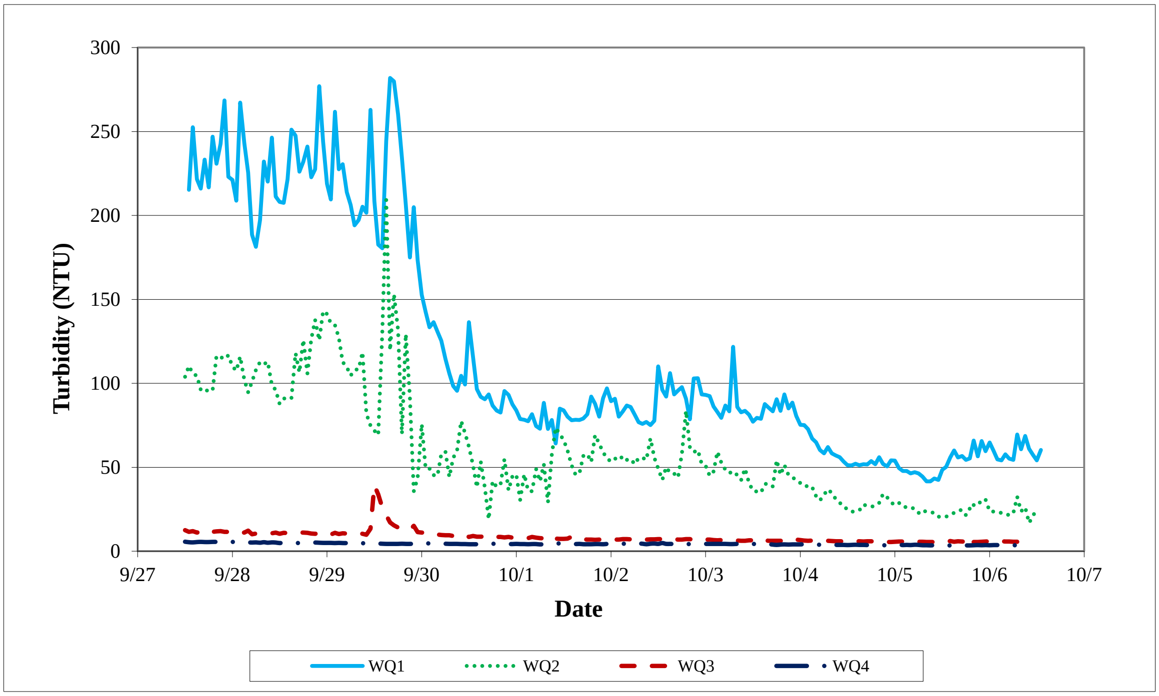

Figure 5-16. Eklutna River turbidity during scheduled flow release.

Table 5-2. Eklutna River turbidity (NTU) during study flow release.

Sample Source	9/27/21	10/6/21
WQ Station 1 (below lower dam removal site/sediment wedge)	140	32.0
WQ Station 2 (below large alluvial fan)	55.0	14.0
WQ Station 3 (upper valley below some minor alluvial fans)	5.10	3.00
WQ Station 4 (upper valley with wooded, stable stream banks)	4.40	2.70

Table 5-3. Eklutna River total suspended solids (mg/l) during study flow release.

Sample Source	9/27/21	10/6/21
WQ Station 1 (below lower dam removal site/sediment wedge)	146	33.3
WQ Station 2 (below large alluvial fan)	88.1	16.3
WQ Station 3 (upper valley below some minor alluvial fans)	7.35	2.23
WQ Station 4 (upper valley with wooded, stable stream banks)	3.77	2.18

6. CONCLUSIONS

The results and conclusions from this study will be utilized during the alternatives analysis to evaluate any potential impacts to water quality that may result from future water management changes. ADEC water quality criteria discussed below are based on values summarized in Table 2-1 (ADEC 2020).

As mentioned in Section 1 of the Year 1 2021 Interim Report, the quality and completeness of the pH, DO, and turbidity data sets represented the final assessment of those three parameters in support of the Water Quality Study. Study efforts continued over the winter and through the fall of 2022 to build upon the 2021 water temperature record. In addition, a second season of chlorophyll *a* sampling was conducted to verify the TSI ranking of Eklutna Lake and the pond and provide supporting data to the "Eklutna Lake Aquatic Habitat and Fish Utilization Study" (Thompson et al. 2023).

6.1. Water Temperature

6.1.1. Eklutna River

During the summer months, water temperatures in the Eklutna River upstream of Thunderbird Creek increased in a downstream direction from WQS 2 to WQS 1 an average of 1.5°C and at times by more than 4°C (Figure 5-1). During the early fall and winter period (October 1-April 1), the trend is reversed, with water temperatures decreasing in a downstream direction by an average of 2.4°C with temperatures intermittently being more than 5°C colder at WQS 1 than WQS 2. The winter monitoring period also reveals that surface water at WQS 2 doesn't approach freezing with a winter low temperature of 2.4°C in the month of March. In contrast, WQS 1 has 39 days of 0°C or freezing conditions from November 1 – March 31, 2021. These data show that groundwater and ambient temperatures have the greatest influence at WQS 2 and WQS 1, respectively. Finally, study flow releases from Eklutna Lake caused a temperature spike $\geq$ 4°C within these stream reaches. However, at no time did mean daily temperatures exceed ADEC's most restrictive criteria of 13°C for fish spawning and egg & fry incubation at either location.

6.1.2. Eklutna Lake

In both Eklutna Lake and the pond, the thermograph data show that surface water temperatures were higher than temperatures at depth by as much as 3-4°C in mid-summer (Figure 5-2 and Figure 5-3). Also, at both Eklutna Lake and the pond, mean daily surface temperatures met the ADEC criteria of $\leq$ 20°C, but exceeded the fish rearing/migration route criteria of $\leq$ 15°C and the spawning/incubation criteria of $\leq$ 13°C. At depth, Eklutna Lake exceeded the $\leq$ 13°C criteria for two days and the $\leq$15°C on one day in early July of 2022. In 2021, the pond met the $\leq$ 15°C criteria, but exceeded $\leq$13°C for 24 days (July 18-August 10, 2021) at a depth adjacent to the drainage outlet gate. In 2022, the pond met both the $\leq$13°C and $\leq$ 15°C criteria for the entire monitoring season at the outlet gate elevation. As expected, the winter temperature data reveal that surface temperatures are colder than at depth from early December to mid-April in Eklutna Lake, while the pond generally exhibits this pattern from mid-October to mid-April. Eklutna Lake and the pond have winter temps averaging 3.1°C and 3.7°C at depth, respectively. These relatively warm winter water temperatures in comparison to ambient conditions need consideration, as frazil ice[2] formation is possible if water from these diversion locations were to be conveyed as turbulent, surface water into the Eklutna River (USACE 1984; USBOR 1971).

[2] Frazil ice is soft or amorphous ice formed by the accumulation of ice crystals in water that is too turbulent to freeze solid

Water temperature profiles in Eklutna Lake indicate minor stratification between the surface and intake structure in August but return to a nearly isothermal condition by late September (Figure 5-4 and Figure 5-5). Temperature profiles in the pond followed a similar pattern, with peak temperatures at the surface and at depth occurring in August. In addition, a uniform temperature condition throughout the water column is detected by September (Figure 5-5 and Figure 5-6). It is also noteworthy that the continuous water temperature data reveal an isothermal condition throughout the water column from mid-April to late May in Eklutna Lake and from mid-April to early May in the pond. Finally, the two years of lake profiling data show that both waterbodies have unique and isolated temperature characteristics, even when they were connected in the fall of 2021 and 2022.

6.1.3. Dissolved Oxygen

With the exception of noisy data during the 150 and 75cfs study flow releases between September 13 and 20, 2021, DO in the Eklutna River upstream of Thunderbird Creek was >10mg/l, in excess of the 7mg/l or greater ADEC criteria for fish (Figure 5-8). Similarly, DO levels in Eklutna Lake exceeded 10mg/l throughout the water column for the monthly depth profiles recorded from June-September (Figure 5-9). In contrast, DO concentrations in the pond were lower than the ADEC criteria of 7mg/l or greater at the depth of the drainage outlet gate on May 20 and June 23, 2021 (Figure 5-11). In addition, the supersaturation of DO profiles in the pond at all depth strata on July 14 and August 25, 2021, indicates some form of photosynthetic activity from aquatic macrophytes and/or phytoplankton (Figure 5-13). Finally, the 2021 lake profiling data show that both waterbodies have unique DO characteristics when isolated but have matching DO concentrations throughout the water column when connected in the fall of 2021.

6.1.4. pH

Eklutna River pH data reveals a noticeable change above and below the lower dam removal site at RM 4.0. Upstream of the dam removal site (WQS 2), pH was primarily at 7.8 for the entire study period. Downstream of the dam removal site at WQS 1, pH consistently hovered around 8.5 and intermittently exceeded the ADEC criteria of 8.5 for fish and other aquatic organisms. Given the low flow volumes (~4-6 cfs) at the two study sites during the existing condition, a tributary or groundwater source of higher pH water would influence the results. This presence of an elevated pH source between the two water quality sites was validated during the study flow releases from Eklutna Lake. During this time, pH at WQS 1 had a detectable and precipitous decrease of ~0.3 pH units that was maintained through the end of the monitoring season (September 29, 2021) during flow releases of 25 cfs. In Eklutna Lake, June-September profile measurements show that pH levels meet the ADEC fish criteria range of 6.5 to 8.5 at all depths. (Figure 5-14). In the pond, a majority of the pH profile measurements from May-September ranged between 7.4 and 8.5 and meet ADEC criteria. The exception occurs at surface and depth measurements on July 14, 2021, and at a depth of 6 feet on August 25, 2021, in which pH values increase to 8.6 (Figure 5-15). These results confirm that Eklutna Lake and the pond have a unique and isolated water quality composition.

6.1.5. Turbidity and Total Suspended Solids

As expected, the 75cfs to 25cfs study flow releases from September 24 – October 6 show that both turbidity and TSS increased moving downstream, with substantial increases at WQS 2, below a distinctly large alluvial fan and WQS 1, below the lower dam removal site (Figure 5-16; Table 5-2 and Table 5-3). ADEC criteria states in Table 2-1 that turbidity "…not exceed 25 NTU above natural conditions" (ADEC 2022). Based on the decreases in turbidity during the study flow down-ramping, the two upper valley sites (WQ3 and WQ4) remained relatively stable with *in situ* data showing turbidity levels changing from 1.7-2.1 NTU as study flows receded. However, in the lower valley (WQ1 and WQ2), *in situ* data show decreases of 41 NTU below the alluvial fan (WQ2) and 108 NTU below the diversion dam sediment wedge (WQ1). Therefore, any up ramping of flow releases has the potential to violate ADEC criteria for an indeterminate amount of time. Despite the lack of TSS criteria described by ADEC, the major composition of these "suspended solids" is sediment (i.e. sand and silt) from alluvial fans and the deposits left behind the diversion dam removal. ADEC does state that sediment loads in the 0.1-0.4mm size class cannot "…cause adverse effects on aquatic animal or plant life, their reproduction or habitat…" (ADEC 2022). Therefore, any movement or flushing of these sediments downstream from controlled flow releases has the potential to foul or clog the interstitial spaces of gravel beds critical for salmonid reproduction.

6.1.6. Eklutna Lake Trophic Status

Although 2 of the 3 parameters sampled in 2021 did not inform the TSI of Eklutna Lake and the pond, Carlson (1977) stated that chlorophyll *a* provides the best indicator of trophic status. The findings in Burgner et. al (1969) appear to verify Carlson's statement with regards to glacially-fed lakes in southwestern Alaska; i.e., Chignik Lake had shallow Secchi depths (1.9 m), but high photosynthetic activity with a chlorophyll *a* concentration of 15.3 ug/l (Burgner, et. al., 1969). In 2021, average TSI values of 18.9 and 27.0 were calculated for Eklutna Lake surface and the pond, respectively. TSI values were lower in 2022 with Eklutna Lake and the pond scoring 10.6 and 9.8, respectively. Despite, the inter-annual and inter-site variability, all TSI values correspond to an oligotrophic classification (TSI <30), representing a lake with low primary productivity. In addition to the USACE (2011) assumption of elevated turbidity decreasing light penetration, low nutrient concentrations are also likely limiting primary productivity within Eklutna Lake. Although there is not a zooplankton density that directly corresponds to the carrying capacity for sockeye salmon in Eklutna Lake, the low algal biomass within Eklutna Lake likely corresponds to low zooplankton densities and appears to be a limiting factor (i.e., food resource) for fish production, especially for resident species such as kokanee. As stated by the USACE (2011), "[l]ow numbers and small size of the native land locked sockeye salmon (kokanee) found in the lake support these biological assumptions."

There is not a systematic study that clearly defines the relationship between turbidity and lake productivity, but the typical trend is that increasing turbidity decreases productivity (ADF&G, 1985). This is trend is exemplified in productive sockeye salmon systems of nearby Skilak and Kenai Lakes. Chlorophyll-*a* concentrations in Skilak and Kenai Lakes are similar to Eklutna Lake, but the increasing levels of glacial silt (i.e. turbidity) in these watersheds have ADF&G scientists concerned. In an interview with Matt Tunseth of the Peninsula Clarion (2004), ADF&G scientist Mark Willette stated their research has shown a consistent trend of sockeye fry getting smaller at the same time that densities of zooplankton (i.e. copepods) are decreasing. In 2004, the average fry weight was 0.6 grams when juvenile sockeye from Skilak Lake would typically weigh more than 1.0 gram. If a critical summer weight size isn't achieved, overwinter survival will be poor and at some point will have a substantial impact on sockeye returns. Willette confirms that the small juvenile sockeye in 2004 is caused by the retreating Skilak Glacier at the head of Skilak Lake. The elevated glacial runoff produces more silt, blocking sunlight, reducing the euphotic zone, and diminishing copepod survival, which is directly correlated to sunlight. The result is fewer organisms available as a food resource for juvenile sockeye (Tunseth 2004). Given that Eklutna Lake has a retreating glacier contributing large volumes of silt, the risks of salmon reintroduction to the lake need to be carefully considered to determine if a viable population can be sustained.

Finally, the data described above (i.e. low nutrient and chlorophyll-*a* concentrations) confirm why Eklutna Lake serves as an excellent source of drinking water. In fact, their latest annual drinking water report states that "AWWU has never violated a maximum contaminant level or any other water quality standard. [Only a] small amount of chlorine or other disinfection method is used to kill bacteria and other microorganisms (viruses, cysts, etc.) that may be in the water before water is stored and distributed to homes and businesses in the community." (AWWU 2022). Therefore, any potential plan to reintroduce anadromous salmon runs that utilize Eklutna Lake needs to carefully consider potential impacts to the public water supply. For comparison, the Cedar River supplies 70% of the public water supply for the City of Seattle. In the Habitat Conservation Plan (HCP) for the Cedar River, the risks of degrading water quality were weighed against passing salmon above the intake dam for the drinking water source (Seattle Public Utilities [SPU] 2000). Although small numbers (~5,000) of chinook, coho, and steelhead would pose a lower risk, it was concluded that "…passing [262,000 adult] sockeye above the raw water intake would pose an unacceptable risk to water quality." Since allowing fish passage in August of 2003, SPU has produced two status reports on the impact of salmon reintroduction to water quality (SPU 2008, 2013). Of particular interest was how the addition of salmon carcasses to the system would impact concentrations of total phosphorus (TP), the nutrient of greatest concern to maintaining water quality for drinking water. Based on a 10-year average of 498 spawning adults per year, TP showed a statistically significant increase in the recently colonized stream reach, whereas the site upstream of fish carcasses showed a slight downward trend in TP (SPU 2013). A monitoring and adaptive management program is ongoing to ensure the HCP target escapement of 4,500 coho and 1,000 Chinook will not raise TP concentrations to the detriment of drinking water quality. Therefore, even the introduction of a relatively small salmon run needs to be assessed and closely monitored, as measurable changes in water quality have been detected in the drinking water supple for the City of Seattle.

7. VARIANCES FROM FINAL STUDY PLAN AND IMPLEMENTED MODIFICATIONS

There were two notable variations from the final approved study plan related to turbidity monitoring and one variation to water temperature monitoring program. Based on the 30-day duration of the flow release schedule, continuous turbidity monitoring was not initiated until the 75 cfs release period began. Mass wasting events, potential equipment loss, instrument battery life and wading safety during the initial 150 cfs period were the primary considerations for delaying the deployment of turbidity instruments until the 75 cfs flow release period. This study variance was discussed and agreed to following consultation with NMFS, the lead agency requesting continuous turbidity monitoring as a part of the Water Quality Study.

The second variance from the final approved study plan was the relocation of WQS 3 from RM 8 upstream to RM 10.3. The formation of a substantial beaver pond downstream of RM 10 limited reliable access to RM 8 of the Eklutna River. Therefore, a site was chosen that had alluvial fan inputs in contrast to the stable banks and minimal alluvial sediment deposits at Water Quality Station 4.

The last variation to the study plan was that thermographs at the Eklutna River and Eklutna Lake sites were left out to collect continuous water temperature data over the winter.

8. REFERENCES

ADEC Alaska Department of Environmental Conservation. 2020. 18 AAC 70 Water Quality Standards Amended as of March 5, 2020. Register 233, April 2022. 65 pages.

ADF&G Alaska Department of Fish and Game. 1985. Turbidity in Freshwatrer Habitats of Alaska; A Review of Published and Unpublished Literature Relevant to the Use of Turbidity as a Water Quality Standard. D.S. Lloyd. Report No, 85-1. 101 pp.

ADF&G Alaska Department of Fish and Game. 2003. Exxon Valdez Oil Spill Restoration Project Final Report. Sockeye Salmon Overescapement (Kenai River Component). Edmundson J.A., T.M. Willette, J.M. Edmundson, D.C. Schmidt, S.R. Carlson, B.G. Blue, and K.E. Tarbox. Restoration Project 96258A-1. October 2003. 49 pp.

Allan, J. David. 1995. Stream Ecology: Structure and Function of Running Waters. Chapman & Hall, London.

APA (Alaska Power Authority). 1984. Susitna Hydroelectric Project Eklutna Lake Temperature and Ice Study. 16 pp with 39 Figures. Submitted January 1984.

APHA American Public Health Association, American Water Works Association, and Water Pollution Control Federation, 2017, Standard methods for the examination of water and wastewater (23rd ed.): Washington, D.C., American Public Health Association, American Water Works Association, Water Environment Federation, [variously paged].

AWWU Anchorage Water and Wastewater Utility. 2022. 2022 Anchorage Water System Consumer Confidence Report PWSID AK 2210906. https://www.awwu.biz/home/showpublisheddocument/2108/637922013792500000

Carlson, R.E. 1977. A trophic state index for lakes. Limnology and Oceanography. 22:2 361-369.

McMillen Jacobs Associates. 2021. Eklutna Hydroelectric Project 1991 Fish & Wildlife Agreement Implementation. Final Study Plans. Prepared for Municipality of Anchorage, Chugach Electric Association, Inc., and Matanuska Electric Association.

R&M (R&M Consultants, Inc.). 1985. Eklutna Lake Suspended Sediment, Turbidity, and Temperature Data 1982-1984. Memorandum submitted 5/1/1985 to Aquatic Study Team Members in support of Project No. 452418. 27 pp.

SPU Seattle Public Utilities. 2000. Final Cedar River Watershed Habitat Conservation Plan For the Issuance of a Permit to Allow Incidental Take of Threatened and Endangered Species. Appendix 5: Analysis of Water Quality Impacts of Allowing Anadromous Fish Above Landsburg. CH2M HILL. 1996. City of Seattle. April 2000.

SPU Seattle Public Utilities. 2008. 2008 Status Report and Adaptive Management Plan. Effects of Salmon above Landsburg on Drinking Water Quality. Seattle Public Utilities Utility Systems Management Branch. August 27, 2014. 21 pp.

SPU Seattle Public Utilities. 2013. Effects of Salmon above Landsburg on Drinking Water Quality. 2013 Status Report. Prepared for Seattle Public Utilities. Prepared by Herrera Environmental Consultants, Inc. June 13, 2008 Draft. 62 pp.

Thompson, A., M. Gagner, A. Shelly, M. Keefe, Kleinshcmidt Associates. 2023. Eklutna Hydroelectric Project Eklutna Lake Aquatic Habitat and Fish Utilization Year 2 Study Report, Draft. Prepared for Municipality of Anchorage, Chugach Electric Association, Inc., and Matanuska Electric Association.

Tunseth, Matt. 2004. Small Fry May be Big Problem. Peninsula Clarion posted November 14, 2004. http://aswc.seagrant.uaf.edu/data/grade8/smallfrybigproblem.pdf

USACE (United States Army Corps of Engineers). 1984. Frazil Ice Formation. Ettema, R., M.F. Karim, and J.F. Kennedy. U.S. Army Cold Regions Research and Engineering Laboratory. CRREL Report 84-18. 44 pp.

USACE (United States Army Corps of Engineers). 2011. Eklutna River Aquatic Ecosystem Restoration Technical Report. Submitted November 2011. 72 pp.

USBOR (Unite State Bureau of Reclamation). 1971. Ice Problems in Winter Operation Recommendations for Research. Burgi, P.H., W.M. Borland, K.J. Greene, R.B. Hayes, and B.J. Peter. Engineering and Research Center. Denver, Colorado. 61 pp.

USGS (U.S. Geological Survey). 1947. Preliminary Report on Water Power Resources of Eklutna Creek, Alaska. Tacoma, Washington. August 1947.

USGS (United States Geological Survey). 1948. USGS 15280000 EKLUTNA C NR PALMER AK. Accessed April 19, 2020. https://waterdata.usgs.gov/nwis/inventory/?site_no=15280000&agency_cd=USGS

USGS (United States Geological Survey). 1949a. USGS 612706149195000 EKLUTNA C BL EKLUTNA DIVERSION DAM NR PALMER AK. Accessed April 19, 2020. https://waterdata.usgs.gov/nwis/inventory/?site_no=612706149195000&agency_cd=USGS

USGS (United States Geological Survey). 1949b. USGS 15280200 EKLUTNA R AT OLD GLENN HWY AT EKLUTNA AK. Accessed April 19, 2020. https://waterdata.usgs.gov/nwis/inventory/?site_no=15280200&agency_cd=USGS

USGS (United States Geological Survey). 1973. USGS 612836149084800 EKLUTNA R BL POWER PLANT NR EKLUTNA AK. Accessed April 19, 2020. https://waterdata.usgs.gov/nwis/inventory/?site_no=612836149084800&agency_cd=USGS

Washington State Department of Ecology Environmental Assessment Program, 2011. Standard Operating Procedures for Continuous Temperature Monitoring of Fresh Water Rivers and Streams. Version 2.0. Author: William J. Ward, Reviewers: Dan Sherratt and Dave Hallock. Approved 10/26/2011, Recertified: 3/25/2015.

Appendix A. Supporting Data Source Files

The supporting data for this report are contained in the following spreadsheet files and are available upon request:

Data	Source file
Eklutna River temperature, DO, pH	Eklutna River pH Temp DO Data.xlsx
Eklutna Lake, Eklutna Pond temperature	Lake_Pond Temp Data.xlsx
Eklutna Lake temperature, DO, pH profiles	Eklutna Lake pH Temp DO Profiles.xlsx
Eklutna Pond temperature, DO, pH profiles	Eklutna Pond pH Temp DO Profiles.xlsx
Eklutna River turbidity	Eklutna River Turbidity.xlsx