AVISTA CORPORATION

LONG LAKE HED TAILRACE DISSOLVED OXYGEN MONITORING REPORT

WASHINGTON 401 CERTIFICATION, SECTION 5.6(B)

Spokane River Hydroelectric Project
FERC Project No. 2545

Prepared By:

AVISTA

April 15, 2021

[Page intentionally left blank]

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ACRONYMS AND ABBREVIATIONS

%	percent
% saturation	percent of saturation
°C	degrees Celsius
7Q10	7-day average flow with a 10-year return period
AC	alternating current
Avista	Avista Corporation
BAR	barometric pressure
cfs	cubic feet per second
DO	dissolved oxygen
DO%	dissolved oxygen percent of saturation
DO TMDL	Dissolved Oxygen Total Maximum Daily Load
DO WQAP	Dissolved Oxygen Water Quality Attainment Plan
DQO	data quality objective(s)
Ecology	Washington State Department of Ecology
FERC	Federal Energy Regulatory Commission
ft amsl	feet above mean sea level
Golder	Golder Associates Inc.
HED	hydroelectric development
m	meter(s)
mg/L	milligrams per liter
mm Hg	millimeters mercury (pressure)
MQO	measurement quality objective
MS5	Hydrolab® MS5 Multiprobe®
LLFB	monitoring station at Long Lake forebay
LLTR	monitoring station at Long Lake tailrace
PDT	Pacific Daylight Time
Project	Spokane River Project
REMI	Reservoir Environmental Management, Inc.
RMSE	root mean squared error
SCCD	Stevens County Conservation District
Spokane Tribe	Spokane Tribe of Indians
TDG	total dissolved gas

1.0 INTRODUCTION

1.1 Background

Water quality monitoring results during the Spokane River Project (Project) relicensing process (HDR 2005) indicate that the Long Lake Hydroelectric Development (HED) discharged water that did not meet the applicable dissolved oxygen (DO) water quality standards at certain times of the year. To address this issue, Avista Corporation (Avista) proposed to conduct a feasibility study to identify potential mechanisms to improve DO levels at the Long Lake HED discharge, evaluate which alternatives are reasonable and feasible, and implement selected alternative(s) to improve DO in the Long Lake HED discharge. Avista initiated this process while relicensing the Project with the Long Lake HED Phase I Aeration Study (HDR 2006).

Avista and the Spokane Tribe of Indians (Spokane Tribe) entered into a non-License Agreement, which addresses DO (and other water quality issues) on the Spokane Tribe's reservation. This Agreement commits Avista to "work collaboratively [with the Spokane Tribe] to develop and carry out feasibility studies and implementation actions pertaining to the goal of meeting the DO, TDG (total dissolved gas), and Temperature requirements at the Reservation boundary."

License Article 401, Appendix B, Condition 5.6(B) of the Washington Section 401 water quality certification (Ecology 2010a) required that Avista "*submit to Ecology a Detailed Phase II Feasibility and Implementation Plan based on the Long Lake HED DO Aeration Study within one year of license issuance (by June 17, 2010), choosing one or several options to implement. The plan shall contain:*

- *Anticipated compliance schedule for conducting preliminary and final implementation plans.*
- *A monitoring plan to evaluate compliance (including avoidance of super-saturation) and coordinate results with the DO TMDL efforts.*"

Avista submitted the Detailed Dissolved Oxygen Phase II Feasibility and Implementation Plan to Washington State Department of Ecology (Ecology) as directed, and Ecology approved it on June 11, 2010 (Avista 2010). Shortly thereafter, DO enhancement testing and monitoring was conducted (HDR and REMI 2010). On December 9, 2010, the Federal Energy Regulatory Commission (FERC; 2010) modified and approved the Feasibility and Implementation Plan. Avista's implementation of the FERC-approved Feasibility and Implementation Plan is documented in the 2011, 2012, and 2013 annual reports (Golder 2012, 2013, and 2014 respectively). Avista's 2014 annual report (Golder 2015) documented 2014 DO conditions along with the Five-Year summary report required under the FERC approved Feasibility and Implementation Plan, which were submitted to Ecology, the Spokane Tribe, and FERC.

Avista has continued to implement this DO enhancement strategy, which includes documenting the 2015, 2016, 2017, 2018, and 2019 actions in an annual report (Golder and Mattax Solutions 2016, Golder and Mattax Solutions 2017, Avista 2018, 2019, and 2020 respectively). The 2016 annual report (Golder and Mattax Solutions 2017) presented the results of the 2016 DO conditions along with an analysis of the monitoring results from the past seven years (2010 through 2016). This current report presents the results of the 2020 DO monitoring immediately downstream of Long Lake Dam for the year's low-flow period and summarizes the use of draft tube aeration to boost DO levels in the river below the dam's tailrace.

1.2 Objectives

The objectives of the DO monitoring plan (Avista 2010) are to:

1. Improve the understanding of the seasonal timing and magnitude of DO levels in the Long Lake HED tailrace, particularly as they relate to the applicable water quality standards.
2. Obtain data for aeration feasibility studies for the Long Lake Dam, powerhouse, and tailrace.
3. Document the effectiveness of meeting the DO water quality standards through measure(s) implemented to increase DO levels of Long Lake HED discharges.
4. Document super-saturation caused by measure(s) implemented to increase DO levels of Long Lake HED discharges.
5. Coordinate results with DO Total Maximum Daily Load (TMDL) efforts.

2.0 METHODS

Water quality parameters that were recorded include DO concentration (milligrams per Liter [mg/L]), TDG pressure (millimeters mercury [mm Hg]), and water temperature (°C). Water depth (meters [m]) was also recorded and used in conjunction with water temperature to evaluate the timing of water quality monitoring instruments being out of water and above the minimum TDG compensation depth.

2.1 Equipment and Calibration

Solinst® barologgers were used to determine local barometric pressure. A primary barologger was deployed at the Long Lake HED pump house for the entire monitoring season. A back-up barologger was also deployed at the pump house for the entire monitoring season to provide local barometric pressure (BAR) data if the primary barologger failed. As an additional quality assurance measure, resulting site-specific barometric pressures were compared to corresponding values for the Spokane International Airport for each site visit. Spokane International Airport station sea-level barometric pressures were downloaded from the Weather Underground[1] and adjusted by subtracting 37.05 mm Hg to account for the altitude of the Long Lake HED tailrace (1,365 feet above mean sea level [ft ams]).

Hydrolab® MS5 Multiprobe® (MS5) instruments with TDG, optical DO, temperature, and depth sensors were used. A MS5 connected to an external alternating current (AC) power source was used upon initial deployment with the goal of minimizing potential issues associated with low or no power supply. In addition, a second MS5 powered solely on internal batteries was deployed

[1]On each site visit day, Spokane, WA KGEG barometric pressure data were downloaded from the History & Almanac section of https://www.wunderground.com/history/airport/KGEG/2017/4/7/DailyHistory.html?req_city=Spokane+International&req_state=WA&req_statename=&reqdb.zip=99224&reqdb.magic=3&reqdb.wmo=99999.

for long-term monitoring and was paired with the AC-powered MS5 to obtain spot measurements of DO, TDG pressure, and temperature.

All Hach instruments used had undergone annual servicing by Hach and were factory calibrated before the 2020 monitoring season. Monitoring equipment was calibrated according to the manufacturer's instructions prior to deployment and on periodic site visits. Pre-deployment field verification included synchronizing the clocks, comparing each MS5's TDG pressure value with the silastic membrane removed to the ambient barometric pressure, confirming the patency of each MS5's TDG silastic membrane, and testing the barologgers to confirm that the recorded values were similar and comparable to those at the Spokane International Airport.

During service periods, each MS5 was retrieved and the pull time was recorded. Each service session included verification of logging status and downloading the data to a portable field computer. The Solinst® barologgers also were downloaded during these service periods. Patency of the original TDG membrane was confirmed by observing a rapid increase in TDG pressure while pressurizing the sensor with soda water. The manufacturer's instructions were implemented to calibrate depth, DO sensors, and to verify the temperature sensors.

2.2 Station Facilities

For this monitoring, MS5 long-term deployments were done at a water quality monitoring facility located 0.6 mile downstream of Long Lake Dam, referred to as LLTR (Table 2-1; Figure 2-1). In agreement with Ecology, the water quality monitoring facilities in the Long Lake HED forebay, referred to as LLFB, was not used in 2020, since water quality conditions at LLTR, not LLFB, are used to refine aeration operations at the Long Lake HED powerplant.

The permanent station at LLTR consisted of a 4-inch-diameter pipe stilling-well (standpipe), which was sealed at the pipe's submerged end to prevent the MS5 from falling out of the pipe. The standpipe had ½-inch-diameter perforations along its sides and a hole at the bottom to provide water exchange between the interior and exterior of the pipe and limit accumulation of sediment and debris in the bottom of the pipe. The standpipe's top end is protected by an enclosed box containing AC power and data communication equipment.

During periods of low tailrace water elevations, the MS5 was removed from the permanent stilling well, placed inside a perforated PVC pipe, and placed directly on the streambed, as near to the outlet of the permanent station's stilling well as possible to ensure the MS5 was consistently under water.

In 2012, Avista installed a real-time data system to transmit MS5 water quality measurements from the LLTR long-term monitoring stations to the HED control room in the powerhouse. A coordinated team of Avista staff, including the HED Operators and water resource specialists, used LLTR's real-time DO and TDG pressure values to select aeration valve openings for each Unit with the goal of meeting the 8-mg/L DO criterion at LLTR without exceeding the 110-percent of saturation TDG criterion.

2.3 Spot Measurements

As a quality assurance measure, spot measurements of DO, TDG pressure, and water temperature were made continuously throughout the sampling season by pairing a secondary

MS5 with the primary MS5. The river is generally well mixed at LLTR, as was determined in 2011 based on paired spot measurements of water temperature, DO, and the percent TDG, for both sides of the river (Golder 2012). Therefore, no spot measurements were conducted across the river during the 2020 monitoring season.

2.4 Data Collection and Processing

Parameters monitored at 15-minute log intervals with the instruments described above included:

- Barometric pressure (mm Hg)
- Air Temperature (°C)
- Depth (m)
- TDG pressure (mm Hg)
- Dissolved Oxygen (mg/L)
- Water Temperature (°C)

In addition, percent of saturation for TDG and DO were computed based on measurements, as:

- TDG = TDG in mm Hg / Barometric pressure in mm Hg x 100
- DO percent of saturation (DO%) was computed using equations in the National Park Service's DO Calculator (Thoma and Mailick. n.d.)

Data downloaded to the laptop computer were transferred to an office server and checked for errors using Microsoft Excel®. Erroneous data were identified, assigned data quality codes, and omitted from the final data set.

Long Lake Dam's operations are monitored and recorded by Avista's internal plant control software which were used to output aeration operations, river discharge passing over the dam's spillway, the discharge passing through the dams units, and a total discharge on a 15 minute basis for the extent of the DO monitoring period.

2.5 Monitoring Difficulties

Very few monitoring difficulties were encountered in 2020. Poor air quality in mid-September delayed the planned September 14 site visit until September 17, resulting in a longer than typical time between site visits. Both MS5s met all calibration standards on the September 17 site visit, therefore these data were included in the final dataset.

All MS5s met data quality objectives (DQOs) and measurement quality objectives (MQOs), and were sent in for factory maintenance after the monitoring season.

3.0 RESULTS

MS5s and barologgers were set to record data for approximately 11,808 15-minute periods (referred to as "continuous" data in this report) from July 1 through October 31 (Table 3-1). Two barologgers deployed at LLTR provided a complete (100 percent of the entire continuous monitoring period) data set for local barometric pressure. Temperature and DO data were successfully obtained for nearly 100 percent of the entire continuous monitoring period, and TDG data was collected for 99.5% of the monitoring period (Appendix A, Table A-4). Spot measurements collected when long-term deployment and/or instrument downloads were conducted[2] were used for the quality assurance/quality control program described in Appendix A.

3.1 Discharge

Combined Long Lake HED generation, spill discharge, and seepage for the July 1 to October 31 monitoring period ranged from approximately 210 to 6,898 cubic feet per second (cfs) (Table 3-2). The maximum discharge occurred in July, when discharge reached 6,898 cfs. Maximum discharge was 4,857 cfs, 4,814 cfs, and 5,190 cfs in August, September, and October, respectively. Average discharge was greatest (2,971 cfs) in July, least (1,627 cfs) in August, and intermediate in September and October (1,647 and 2,492 cfs, respectively).

3.2 Water Temperature

Tailrace (LLTR) water temperature ranged from 16.9°C to 19.8°C in July and reached a seasonal maximum of 20.3°C on September 8 (Figure 3-1). Water temperatures began cooling around the middle of September and steadily cooled to less than 11°C at the end of October (Figure 3-1). A short-term increase in water temperature and DO was observed on September 8 through September 9. The increase was likely caused by the strong wind event that took place on September 7, with gusts measuring as high as 44 mph at the Spokane International Airport, likely leading to the mixing of Lake Spokane's surface layer with waters of the interflow layer.

3.3 Barometric Pressure

Site-specific barometric pressures ranged from 711 to 737 mm Hg based on the Solonist® barologgers deployed at LLTR (Table 3-1).

3.4 Dissolved Oxygen

LLTR DO concentrations (recorded during generation and non-generation) ranged from 6.5 to 9.8 mg/L with the greatest consistent DO concentrations near the beginning and the end of the monitoring period (Figure 3-1). Dissolved oxygen initially decreased to below 8.0 mg/L on July 31 and consistently fell below 8.0 mg/L through mid-September (Figure 3-1). Aeration was used sporadically from August 8 to August 10 and then consistently from August 11 through October 20. Figures 3-2 through 3-5 display DO and TDG trends along with aeration operations throughout the progression of the low flow season. These figures show that the daily DO cycle at LLTR peaked in the early afternoon and was lowest in the morning, coinciding with the HED generating schedule. Additional information on the HED's operations, use of spillgates, aeration

[2] This occurred on June 26, July 7, July 22, August 4, August 17, August 31, September 17, September 29, October 13, October 26, and October 31.

operation, and the corresponding frequency of LLTR DO values less than 8.0 mg/L are presented in Table 3-3.

During periods of generation, DO values at LLTR were less than the 8.0-mg/L criterion 11.2 percent of the time during the DO monitoring season (Table 3-3 and 3-4). DO concentrations remained above 8.0 mg/L in July and late October. Of the DO measurements below 8.0 mg/L, 60 percent were within 0.2 mg/L of 8.0 mg/L (i.e. 7.8 and 7.9 mg/L, Figure 3-6) with the minimum DO of 6.5 mg/L occurring in the first half of September (Table 3-4). The 2020 aeration operations are summarized in Section 3.6.

DO and other water quality parameters monitored at LLTR when neither generation nor aeration occurred are summarized in Table 3-5. LLTR's minimum DO concentration for non-generation periods was 7.0 mg/L, which occurred in the last two weeks of August. Non-generation DO values for LLTR were less than the 8.0-mg/L DO criterion for 42.8 percent of the measured values (Table 3-5). Non-generation DO concentrations of less than 8.0 mg/L did not occur the first two weeks and the last two weeks of the monitoring season, but occurred throughout the rest of the monitoring season (Table 3-5). These low DO concentrations were within 0.2 mg/L of 8.0 mg/L (i.e. 7.8 and 7.9 mg/L) 52 percent of the time.

Table 3-6 includes a summary of DO values for the entire July 1 through October 31 monitoring season. The frequency for DO less than 8.0 mg/L was greater during non-generation times than when the dam was generating.

Calculated DO% saturation values ranged from approximately 70.2 to 109.1 percent for LLTR (Table 3-1, Figure 3-7). DO% saturation for LLTR ranged from 70.2 to 109.1 percent during periods of generation (Table 3-4) and from 75.3 to 106.2 percent during non-generation (Table 3-5).

3.5 Total Dissolved Gas

The range of TDG percent was 94.6 to 113.4 percent of saturation for LLTR (Table 3-1). Percent TDG of Long Lake HED discharges monitored at LLTR were greater than the 110 percent criterion for 626 (9.6 percent) of the 6,489 values during generation (Table 3-7, Figure 3-6). Tables 3-3 and 3-4 provide additional insight into the HED operations coinciding with these TDG values over 110%. These exceedances of the 110 percent of saturation criterion occurred a few times in early August and then more consistently from late August through late September (Figures 3-3 and 3-4). TDG was also greater than the 110 percent of saturation criterion during non-generation in this period with an overall frequency of 3.2 percent of the monitoring season (Table 3-7).

3.6 Aeration

Dissolved oxygen levels were monitored from July 1, 2020 through October 31, 2020. Avista operated the HED at varying capacities throughout this period with no spillway releases. Aeration was used sporadically from August 8 to August 10 and then consistently from August 11 through October 20, using different aeration valve openings for Units 1, 2, 3, and 4. Aeration was conducted for a total of 1,700 unit-hours with 1 hour for a single unit, 1,504 hours for two units simultaneously, and 195 hours for three units simultaneously, and 0 unit-hours for four units simultaneously.[3] The various generating and aeration conditions along with comparisons of DO and TDG during generation, as measured at LLTR to their applicable criteria, are summarized below and in Tables 3-3 and 3-4.

Key conclusions for the 2020 monitoring period, presented by month, are:

- **July**: Aeration was not used in July. DO was above the 8.0-mg/L criterion at LLTR during July. These operations did not result in elevating TDG to greater than the 110 percent criterion, with a maximum TDG value of 109.5 percent of saturation.
- **August**: Aeration was used sporadically from August 8 to August 10 and then consistently from August 11 through October 20, with one to three units being used simultaneously, resulting in a total of 445 unit-hours of aeration. These operations resulted in DO meeting the 8.0-mg/L criterion at a frequency of 96.1 percent early in the month and 75.4 percent late in the month. These operations also resulted in elevating TDG to greater than the 110 percent criterion at a frequency of 0.9 percent early in the month and 24.9 percent late in the month, with a maximum TDG of 113.4 percent of saturation.
- **September**: Aeration was conducted daily with two to three units simultaneously, for a total of 716 unit-hours of aeration. These operations resulted in DO meeting the 8.0-mg/L criterion at a frequency of 50.5 percent early in the month and 72.3 percent late in the month. These operations also resulted in elevating TDG to greater than the 110 percent criterion early in the month at a frequency of 33.4 percent and 35.3 percent late in the month, with a maximum TDG of 112.3 percent of saturation.
- **October**: Aeration was conducted through October 20 with one to three units being used simultaneously, for a total of 542 unit-hours of aeration. These operations resulted in DO meeting the 8.0-mg/L criterion at a frequency of 93.6 percent early in the month and 100 percent late in the month and did not cause TDG of greater than the 110 percent criterion.

Results of this study demonstrate the continued work Avista puts towards meeting the DO criterion through aeration of the units at Long Lake Dam. From July 1 through October 31 of 2020, daily aeration enabled DO in powerhouse discharges to satisfy the 8.0-mg/L DO criterion approximately 88.8 percent of the time (Table 3-4) and to be within measurement accuracy (i.e., 7.8 mg/L or greater) 95.5 percent of the time (Figure 3-6). Aeration operations maintained TDG that was less than the upper limit of 110 percent of saturation criterion 90.4 percent of the time (Table 3-4). Avista will continue to refine the use of real-time DO and TDG pressure measurements for selecting aeration valve openings, with the goal of providing additional improvements in DO while limiting adverse TDG conditions.

[3] 1,700 unit-hours = (1 unit x 1 hours) + (2 units x 752 hours) + (3 units x 65 hours)

4.0 DISCUSSION

Avista continues to refine its efforts towards addressing low DO concentrations in Long Lake HED discharges in accordance with the approved schedule (Figure 4-1). The 2020 percentage of DO concentration values greater than or equal to 8.0 mg/L represent 88.8 percent of the entire generation period and 74.7 percent of the entire monitoring period (both generation and non-generation; Table 4-1). Percent TDG was below the 110 percent criterion 90.4 percent of the season during generation and 93.2 percent of the entire monitoring period (including both generation and non-generation; Table 4-1). With these results, Avista plans to continue draft tube aeration operations with adaptive management to improve the effectiveness, using real-time water quality monitoring results.

Avista and others have also implemented measures to improve DO upstream of Long Lake dam. This includes upstream wastewater dischargers working to reduce their point source nutrient loads as well as efforts by Ecology and local conservation districts to reduce nutrient loads from non-point sources (e.g. tributaries and groundwater) in both Washington and Idaho in order to meet the goal of the Spokane River and Lake Spokane DO Total Maximum Daily Load (Ecology 2010b). Additionally, Avista has been implementing its Lake Spokane DO Water Quality Attainment Plan (DO WQAP, Avista and Golder 2012) since 2012. The DO WQAP discussed nine feasible potential measures to improve DO conditions in Lake Spokane, identified a baseline monitoring program, implementation activities, and has an annual reporting component. Implementation activities completed in 2020 are summarized in the Lake Spokane DO WQAP 2020 Annual Summary Report (Avista 2021).

Based on the effectiveness of the draft tube aeration program, combined with other measures being implemented to improve DO in Lake Spokane, no new or additional enhancement measures are necessary to meet the Water Quality Standard below Long Lake HED.

4.1 Need for Additional Monitoring

In order to adequately operate the draft tube aeration system for improving DO, but not cause the TDG criterion to be exceeded, there is a continued need for monitoring DO and TDG at LLTR and using the real-time data system to transmit water quality measurements from LLTR to the HED control room in the powerhouse. LLTR monitoring will follow the same procedures used in previous monitoring seasons, as described in the Detailed Dissolved Oxygen Phase II Feasibility and Implementation Plan (Avista 2010). As in previous monitoring seasons, Avista does not plan to monitor at LLFB, since water quality data from LLFB are not used for selecting aeration operations.

Avista will continue to monitor DO and TDG at LLTR and will work with Ecology and the Spokane Tribe to determine the need for providing future annual reports of the aeration, DO and TDG monitoring results following completion of the DO critical season.

5.0 REFERENCES

Avista Corporation (Avista). 2010. Detailed Dissolved Oxygen Phase II Feasibility and Implementation Plan, Washington 401 Certification, Section 5.6(B). Prepared by Golder Associates Inc. June 11.

______. 2018. 2017 Long Lake HED Tailrace Dissolved Oxygen Monitoring Report. Washington 401 Certification, Section 5.6(B). Spokane River Hydroelectric Project FERC Project No. 2545. April 13.

______. 2019. 2018 Long Lake HED Tailrace Dissolved Oxygen Monitoring Report. Washington 401 Certification, Section 5.6(B). Spokane River Hydroelectric Project FERC Project No. 2545. April 12.

______. 2021. Lake Spokane Dissolved Oxygen Water Quality Attainment Plan 2020 Annual Summary Report. Washington 401 Certification, Section 5.6. Spokane River Hydroelectric Project FERC Project No. 2545. January 29.

______. 2020. 2019 Long Lake HED Tailrace Dissolved Oxygen Monitoring Report. Washington 401 Certification, Section 5.6(B). Spokane River Hydroelectric Project FERC Project No. 2545. April 14.

Federal Energy Regulatory Commission (FERC). 2010. Project No. 2545-125 Order Modifying and Approving Dissolved Oxygen Feasibility and Implementation Plan for the Long Lake Development – Article 401. Issued December 9.

Golder Associates Inc. (Golder). 2012. 2011 Long Lake HED Tailrace Dissolved Oxygen Monitoring Report, Washington 401 Certification, Section 5.6(B). Prepared for Avista Corporation. February 16.

______. 2013. 2012 Long Lake HED Tailrace Dissolved Oxygen Monitoring Report, Washington 401 Certification, Section 5.6(B). Prepared for Avista Corporation. April 10.

______. 2014. 2013 Long Lake HED Tailrace Dissolved Oxygen Monitoring Report, Washington 401 Certification, Section 5.6(B). Prepared for Avista Corporation. April 10.

______. 2015. Five-Year Long Lake HED Tailrace Dissolved Oxygen Monitoring Report, Washington 401 Certification, Section 5.6(B). Prepared for Avista Corporation. April 14.

Golder Associates Inc. and Mattax Solutions LLC (Golder and Mattax Solutions). 2016. 2015 Long Lake HED Tailrace Dissolved Oxygen Monitoring Report, Washington 401 Certification, Section 5.6(B). Prepared for Avista Corporation. April 11.

______. 2017. 2016 Long Lake HED Tailrace Dissolved Oxygen Monitoring Report, Washington 401 Certification, Section 5.6(B). Prepared for Avista Corporation. April 12.

HDR Engineering (HDR). 2005. Spokane River Hydroelectric Project Current Operations Water Quality Report. Prepared for Water Resources Work Group Spokane River Project Relicensing and Avista Utilities. May 9.

______. 2006. Final Report, Long Lake Hydroelectric Development Phase 1 Aeration Study. Prepared for Avista Utilities, Spokane, WA. June 1.

HDR Engineering and Reservoir Environmental Management, Inc. (HDR and REMI). 2010. Phase II Dissolved Oxygen Improvement Project Long Lake HED Hydroelectric Plant Discharge. Prepared for Avista, Spokane, WA. February 25.

Thoma, David and Matt Malick. n.d. Dissolved Oxygen and pH Calculator Read Me File. Version 1.0. U.S. Department of the Interior. National Park Service.

Washington State Department of Ecology (Ecology). 2010a. 401 Certification-Order Spokane River Hydroelectric Project, Certification Amended Order No. 7792, FERC License No. 2545, As amended May 8, 2009 by Order 6702. Prepared by Eastern Regional Office Water Quality Program staff, Spokane, WA. May 20.

Washington State Department of Ecology (Ecology). 2010b. Spokane River and Lake Spokane Dissolved Oxygen Total Maximum Daily Load, Water Quality Improvement Report. Publication No. 07-10-073. Revised February 2010.

TABLES

Table 2-1. Long Lake HED dissolved oxygen monitoring station.

Station Code	Description	Latitude / Longitude (NAD83)	Monitoring Type
LLTR	On left downstream bank, at a water pump house approximately 0.6 mile downstream from Long Lake dam	47°37'48"/ 117°31'47"	Long-term

Table 3-1. Summary of 2020 continuous water quality monitoring results.

Parameter	LLTR		
	Minimum	Maximum	Count
Date/Time (PDT)	7/1/2020 0:00	10/31/2020 23:45	11,808
Water Temperature (°C)	10.6	20.3	11,777
Dissolved Oxygen (mg/L)	6.5	9.8	11,776
BAR (mm Hg)	711	737	11,806
TDG (mm Hg)	687	816	11,749
TDG (% of saturation)	94.6	113.4	11,747
Dissolved Oxygen (% of saturation)	70.2	109.1	11,774

Table 3-2. Monthly outflow from Long Lake HED.

Month - Year	Minimum Discharge (cfs)	Maximum Discharge (cfs)	Average Discharge (cfs)
July 2020	210	6,898	2,971
August 2020	210	4,857	1,627
September 2020	210	4,814	1,647
October 2020	210	5,190	2,492
July through October 2020	210	6,898	2,188

Table 3-3. Summary of exceedances of dissolved oxygen and total dissolved gas at LLTR during generation.

Period		Operations, Spill, and Aeration Characteristics			LLTR DO					LLTR TDG			
Start	Stop	Operations	Spill	Aeration	Total Number	Number DO <8.0 mg/L	Frequency DO <8.0 mg/L	Min DO (mg/L)	Min DO (%)	Total Number	Number >110.0% [1]	Frequency >110.0% [1]	Max TDG (%)
7/1/20 0:00	7/20/20 0:00	1 to 4 units, capacity varies, generation during portion of the day	No	No units used	1,236	0	0.0%	8.4	91.0	1,232	0	0.0%	109.5
7/20/20 0:15	8/4/20 23:45	1 to 3 units, capacity varies, generation during portion of the day	No	No units used	793	0	0.0%	8.0	90.6	787	0	0.0%	108.6
8/5/20 0:00	8/8/20 19:45	2 to 3 units, capacity varies, generation during portion of the day	No	No units used	177	2	1.1%	7.7	86.9	177	0	0.0%	106.9
8/8/20 20:00	8/15/20 17:00	2 to 3 units, capacity varies, generation during portion of the day	No	2 units used sometime each day	304	25	8.2%	7.4	83.5	304	6	2.0%	112.4
8/15/20 17:15	8/31/20 10:00	1 to 3 units, capacity varies, generation during portion of the day	No	3 units used sometime each day	593	136	22.9%	6.7	74.1	589	132	22.4%	113.4
8/31/20 10:15	9/6/20 16:00	1 to 2 units, capacity varies, generation during portion of the day	No	2 units used sometime each day	233	75	32.2%	6.9	76.7	230	90	39.1%	112.3
9/6/20 16:15	9/17/20 14:45	2 to 3 units, capacity varies, generation during portion of the day	No	3 units used sometime each day	443	276	62.3%	7.0	77.4	440	143	32.5%	111.5
9/17/20 15:00	9/30/20 15:45	2 units, capacity varies, generation during portion of the day	No	2 units used sometime each day	698	167	23.9%	6.5	70.2	695	255	36.7%	111.3
9/30/20 16:00	10/1/20 18:15	2 to 3 units, capacity varies, generation during portion of the day	No	3 units used sometime each day	70	2	2.9%	7.7	81.1	70	0	0.0%	104.6
10/1/20 18:30	10/11/20 17:00	1 to 2 units, capacity varies, generation during portion of the day	No	2 units used sometime each day	514	47	9.1%	7.6	78.8	514	0	0.0%	107.8
10/11/20 17:15	10/12/20 8:15	2 to 3 units, capacity varies, generation during portion of the day	No	3 units used sometime each day	17	1	5.9%	7.9	83.1	17	0	0.0%	106.1
10/12/20 8:30	10/16/20 17:45	1 to 3 units, capacity varies, generation during portion of the day	No	2 units used sometime each day	261	1	0.4%	7.9	81.8	258	0	0.0%	104.1
10/16/20 18:00	10/18/20 21:15	2 to 3 units, capacity varies, generation during portion of the day	No	3 units used sometime each day	114	0	0.0%	8.0	83.1	114	0	0.0%	103.2
10/18/20 21:30	10/20/20 17:15	2 to 3 units, capacity varies, generation during portion of the day	No	2 units used sometime each day	117	0	0.0%	8.5	87.0	117	0	0.0%	102.9
10/20/20 17:30	10/31/20 23:45	2 to 4 units, capacity varies, generation during portion of the day	No	No units used	949	0	0.0%	8.3	84.5	945	0	0.0%	103.2
7/1/20 0:00	10/31/20 23:45	1 to 4 units, capacity varies, generation during portion of the day	No	3 units used sometime each day	6,519	732	11.2%	6.5	70.2	6,489	626	9.6%	113.4

Notes:
1. 110% TDG criterion is not applicable when discharge exceeds the 7-day average flow with a 10-year return period, which is referred to as the 7Q10.

Table 3-4. Semi-monthly summary of water quality and operations during generation.

Period		HED Operations				LLTR Water Temperature		LLTR DO			LLTR DO%				LLTR TDG%		
Start	Stop	Generation (hours)	Spill (hours)	Average Total Discharge (cfs)	Aeration (unit-hours)	Total Number 15-Min Values	Average Water Temp (°C)	Total Number 15-Min Values	Min DO (mg/L)	Frequency <8.0 mg/L	Total Number 15-Min Values	Min DO%	Max DO%	Frequency <80.0%	Total Number 15-Min Values	Max TDG%	Frequency >110.0% [1]
7/1/20 0:00	7/15/20 23:45	255	0	5,018	0	1,019	17.7	1,019	8.4	0.0%	1,018	91.0	109.1	0.0%	1,015	109.5	0.0%
7/16/20 0:00	7/31/20 23:45	206	0	4,084	0	820	18.9	820	8.2	0.0%	820	94.1	107.6	0.0%	817	108.6	0.0%
8/1/20 0:00	8/15/20 23:45	172	0	3,301	100	684	19.4	684	7.4	3.9%	684	83.5	104.1	0.0%	681	112.4	0.9%
8/16/20 0:00	8/31/20 23:45	154	0	3,461	345	613	19.0	613	6.7	24.6%	613	74.1	99.6	0.0%	606	113.4	24.9%
9/1/20 0:00	9/15/20 23:45	143	0	3,204	304	572	18.5	572	6.9	49.5%	572	76.7	108.0	1.2%	572	112.3	33.4%
9/16/20 0:00	9/30/20 23:45	199	0	3,141	412	793	17.0	793	6.5	27.7%	793	70.2	93.6	2.8%	787	111.3	35.3%
10/1/20 0:00	10/15/20 23:45	198	0	3,192	405	791	15.6	791	7.6	6.4%	791	78.8	96.9	0.4%	788	107.8	0.0%
10/16/20 0:00	10/31/20 23:45	307	0	3,735	134	1,227	12.8	1,227	8.0	0.0%	1,226	81.8	92.8	0.0%	1,223	103.2	0.0%
7/1/20 0:00	10/31/20 23:45	1,636	0	3,721	1,699	6,519	17.0	6,519	6.5	11.2%	6,517	70.2	109.1	0.6%	6,489	113.4	9.6%

Notes:
1. 110% TDG criterion is not applicable when discharge exceeds the 7-day average flow with a 10-year return period, which is referred to as the 7Q10.

Table 3-5. Semi-monthly summary of water quality and operations during non-generation.

Period		HED Operations				LLTR Water Temperature		LLTR DO			LLTR DO%				LLTR TDG%		
Start	Stop	Non-Generation (hours)	Spill (hours)	Average Total Discharge (cfs)	Aeration (unit-hours)	Total Number 15-Min Values	Average Water Temp (°C)	Total Number 15-Min Values	Min DO (mg/L)	Frequency <8.0 mg/L	Total Number 15-Min Values	Min DO%	Max DO%	Frequency <80.0%	Total Number 15-Min Values	Max TDG%	Frequency >110.0% [1]
7/1/20 0:00	7/15/20 23:45	104	0	210	0	418	17.5	418	8.3	0.0%	418	90.6	103.9	0.0%	418	107.7	0.0%
7/16/20 0:00	7/31/20 23:45	178	0	210	0	712	18.6	711	7.8	1.0%	711	89.0	104.3	0.0%	712	107.5	0.0%
8/1/20 0:00	8/15/20 23:45	188	0	210	0	752	19.3	752	7.3	51.3%	752	82.8	99.9	0.0%	752	106.0	0.0%
8/16/20 0:00	8/31/20 23:45	230	0	210	0	915	19.0	915	7.0	74.4%	915	78.3	98.2	0.7%	915	112.1	3.3%
9/1/20 0:00	9/15/20 23:45	217	0	210	0	868	18.5	868	7.1	68.9%	868	78.8	106.2	0.6%	868	111.9	9.7%
9/16/20 0:00	9/30/20 23:45	160	0	215	0	641	16.9	641	7.3	57.1%	641	78.1	92.7	1.4%	641	111.0	8.3%
10/1/20 0:00	10/15/20 23:45	161	0	210	0	646	15.6	646	7.1	32.0%	646	75.3	93.7	0.5%	646	105.8	0.0%
10/16/20 0:00	10/31/20 23:45	73	0	210	0	294	13.8	294	8.0	0.0%	294	82.1	90.9	0.0%	294	102.5	0.0%
7/1/20 0:00	10/31/20 23:45	1,312	0	211	0	5,246	17.8	5,245	7.0	42.8%	5,245	75.3	106.2	0.4%	5,246	112.1	3.2%

Notes:
1. 110% TDG criterion is not applicable when discharge exceeds the 7-day average flow with a 10-year return period, which is referred to as the 7Q10.

Table 3-6. Summary of dissolved oxygen less than 8.0 mg/L, dissolved oxygen criterion lower limit.

Parameter	LLTR		
	Total Number	Number <8.0 mg/L DO	Frequency <8.0 mg/L DO
Generation With Spill > 200 cfs	0	0	na
Generation With Spill ≤ 200 cfs	0	0	na
Generation Without Spill [1]	6,519	732	11.2%
All Generation [1]	6,519	732	11.2%
Non-Generation [2]	5,245	2,245	42.8%
All	11,776	2,977	25.3%

Notes:
1. Of the 6,519 measurements, 292 (4.5%) were less than 7.8 mg/L.
2. Of the 5,245 measurements, 1,072 (20.4%) were less than 7.8 mg/L.

Table 3-7. Summary of total dissolved gas (%) greater than 110.0%, the total dissolved gas criterion upper limit.

Parameter	LLTR Total Number	LLTR Number >110% TDG [2]	LLTR Frequency >110% TDG
Generation With Spill > 200 cfs [1]	0	0	na
Generation With Spill <200cfs	0	0	na
Generation Without Spill	6,489	626	9.6%
All Generation [2]	6,489	626	9.6%
Non-Generation [3]	5,246	167	3.2%
All	11,735	793	6.8%

Notes:

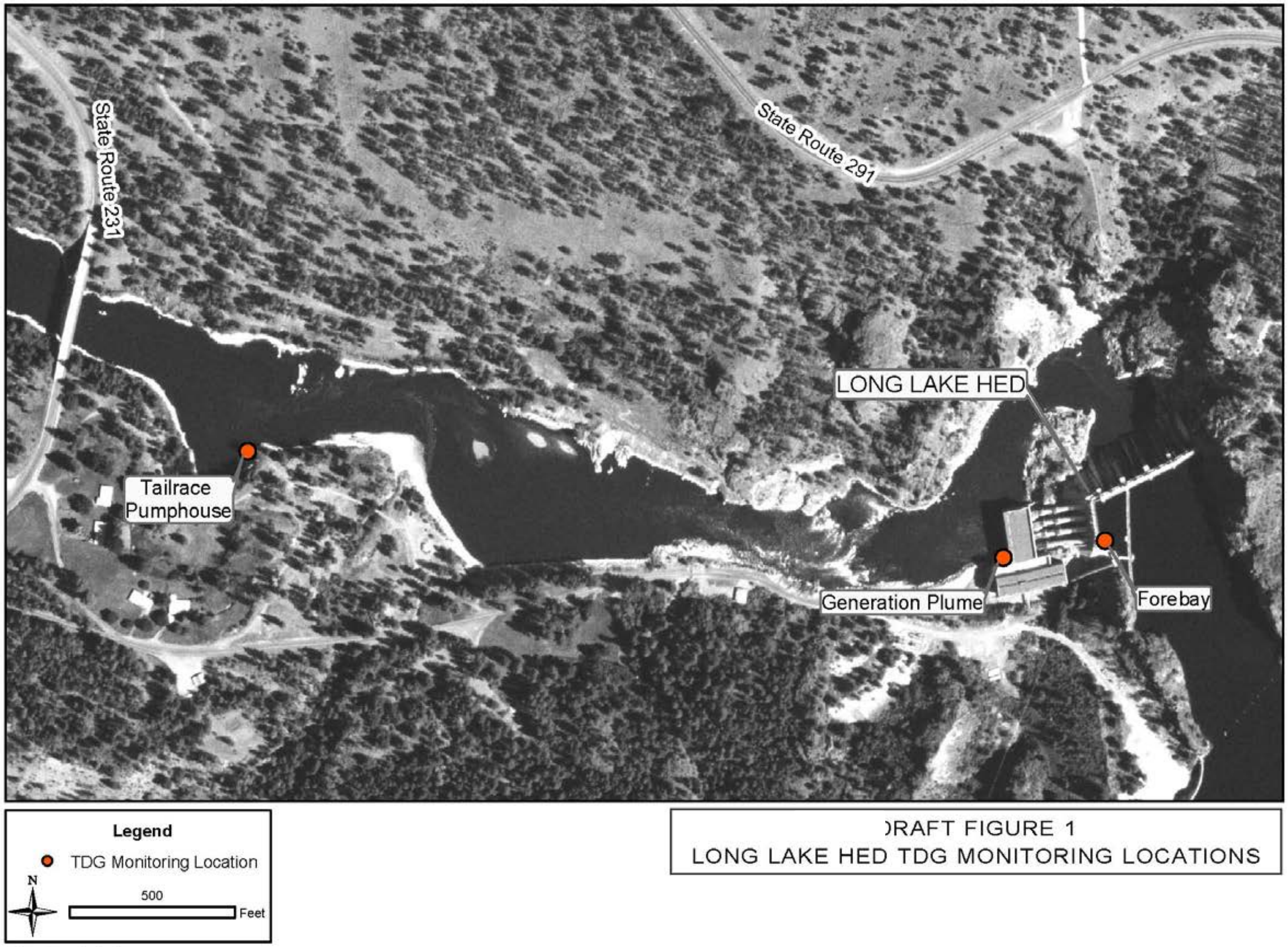
1. 110% TDG criterion is not applicable when discharge exceeds the 7-day average flow with a 10-year return period, which is referred to as the 7Q10.
2. Of the 6,489 measurements, 23 (.4%) were greater than 112%.
3. Of the 5,246 measurements, 1 (0.0%) was greater than 112%.

Table 4-1. Aeration operations and frequency of meeting dissolved oxygen and total dissolved gas criteria.

	2010[a]	2011[b]	2012[c]	2013[d]	2014[e]	2015[f]	2016[g]	2017[h]	2018[i]	2019[j]	2020
Long Lake HED Operations											
Average July - October Discharge (cfs)	nr	3,819	2,941	2,298	2,441	1,396	2,270	2,468	2,210	1,155	2,188
HED Units with Aeration	Tested aeration of Units 3 and 4	Units 3 and 4 with no more than 1 unit aerating at same time	Units 1 and 2 with up to 2 units aerating at same time	Units 1, 2, 3, and 4 with up to 3 units aerating at same time	Units 1, 2, 3, and 4 with up to 3 units aerating at same time	Units 1, 2, 3, and 4 with up to 3 units aerating at same time	Units 1, 2, 3, and 4 with up to 3 units aerating at same time	Units 1, 2, 3, and 4 with up to 3 units aerating at same time	Units 1, 2, 3, and 4 with up to 3 units aerating at same time	Units 1, 2, 3, and 4 with up to 4 units aerating at same time	Units 1, 2, 3, and 4 with up to 3 units aerating at same time
Aeration start and end dates, respectively	September 1 and 2	August 24 and October 19	August 2 and October 14	August 6 and October 6	July 24 and October 21	July 1 and October 31	July 7 and October 11	July 17 and October 18	August 1 and October 8	July 2 and October 8	August 8 and October 20
Aeration Hours	25 unit-hours within 14 hours	684 unit-hours within 684 hours	1,687 unit-hours within 1,021 hours	1,562 unit-hours within 859 hours	2,282 unit-hours within 1,045 hours	2,204 unit-hours within 1,000 hours	1,944 unit-hours within 976 hours	1,992 unit-hours within 1,002 hours	1,657 unit-hours within 701 hours	437 unit-hours within 201 hours	1,700 unit-hours within 818 hours
Frequency LLTR Dissolved Oxygen ≥8.0 mg/L											
During Generation without Spillgate Use[l]	Test results indicate aeration could achieve DO of 7.5 and 8 mg/L while maintaining TDG% <110%	80.8% of 6,709 values	84.7% of 8,272 values	91.5% of 6,826 values	87.4% of 6,656 values	65.1% of 4,434 values	95.6% of 7,039 values	97.4% of 7,130 values	90.8% of 6,231 values	94.4% of 6,198 values	88.8% of 6,519 values
During Generation with Spillgate Use[k]		100.0% of 1,472 values	100.0% of 484 values	zero values	100.0% of 4 values	zero values	zero values	zero values	zero values	zero values	zero values
Entire Generation Period		84.2% of 8,181 values	85.5% of 8,756 values	91.5% of 6,826 values	87.4% of 6,660 values	65.1% of 4,434 values	95.6% of 7,039 values	97.4% of 7,130 values	90.8% of 6,231 values	94.4% of 6,198 values	88.8% of 6,519 values
Entire Monitoring Period (Both Generation and non-Generation)		67.2% of 11,787	67.6% of 11,786	75.0% of 11,772 values	74.3% of 11,445 values	49.4% of 11,764 values	85.7% of 11,733 values	86.7% of 11,585 values	80.8% of 11,762 values	78.6% of 11,410 values	74.7% of 11,776 values
Frequency LLTR TDG% ≤110.0%											
During Generation without Spillgate Use[k]	Test results documented that draft-chest aeration could cause TDG% >110%	99.9% of 6,676 values	96.2% of 8,262 values	88.8% of 6,825 values	86.6% of 6,773 values	88.3% of 4,420 values	91.8 of 7,017 values	99.0% of 7,065 values	95.9% of 6,211 values	97.3% of 5,687 values	90.4% of 6,489 values
During Generation with Spillgate Use[l]		0.7% of 1,467 values	4.3% of 484 values	zero values	75.0% of 4 values	zero values	zero values	zero values	zero values	zero values	zero values
Entire Generation Period		82.0% of 8,143 values	91.1% of 8,746 values	88.8% of 6,825 values	86.6% of 6,777 values	88.3% of 4,420 values	91.8% of 7,017 values	99.0% of 7,065 values	95.9% of 6,211 values	97.3% of 5,687 values	90.4% of 6,489 values
Entire Monitoring Period (Both Generation and non-Generation)		87.6% of 11,748	93.4% of 11,773	93.9% of 11,768 values	90.5% of 11,616 values	95.1% of 11,750 values	94.2% of 11,701 values	99.3% of 11,519 values	97.3% of 11,731 values	98.5% of 10,594 values	93.2% of 11,735 values

Notes:
nr = data not analyzed
[a] September 1 and 2, 2010 aeration testing is documented in HDR and REMI (2010, Section 7.0 and Appendix C).
[b] 2011 Monitoring is documented in Golder (2012).
[c] 2012 Monitoring is documented in Golder (2013).
[d] 2013 Monitoring is documented in Golder (2014).
[e] 2014 Monitoring is documented in Golder (2015).
[f] 2015 Monitoring is documented in Golder and Mattax Solutions (2016).
[g] 2016 Monitoring is documented in Golder and Mattax Solutions (2017).
[h] 2017 Monitoring is documented in Avista (2018).
[i] 2018 Monitoring is documented in Avista (2019).
[j] 2019 Monitoring is documented in Avista (2020).
[k] Includes periods of <200 cfs spill in 2014 and 2015.
[l] Excludes periods of <200 cfs spill in 2014 and 2015.

FIGURES



Source: Avista

Figure 2-1: Long Lake HED long-term water quality monitoring locations.

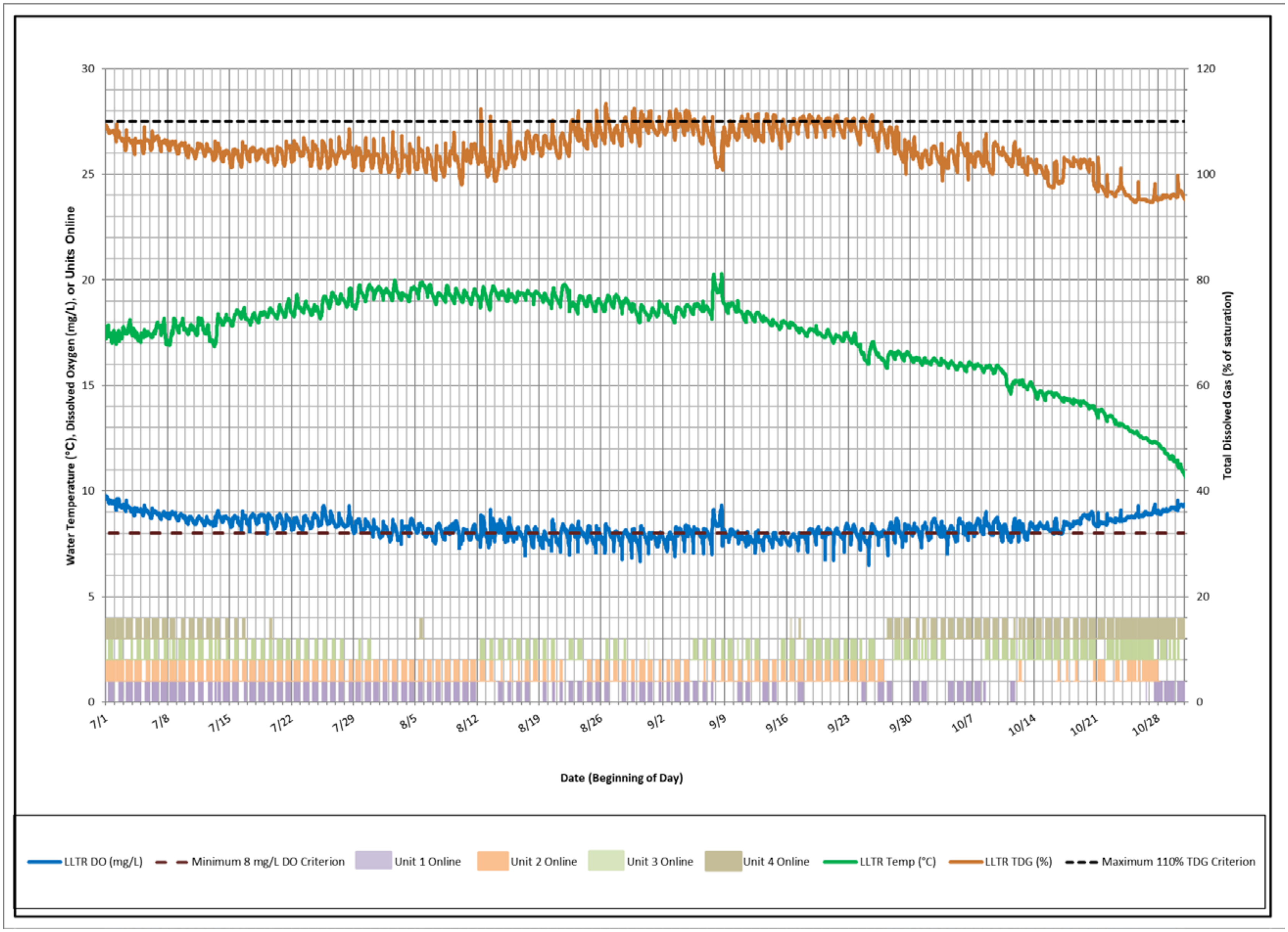


Figure 3-1: LLTR 2020 water temperature (°C), dissolved oxygen (mg/L), total dissolved gas (% of saturation), and operations.

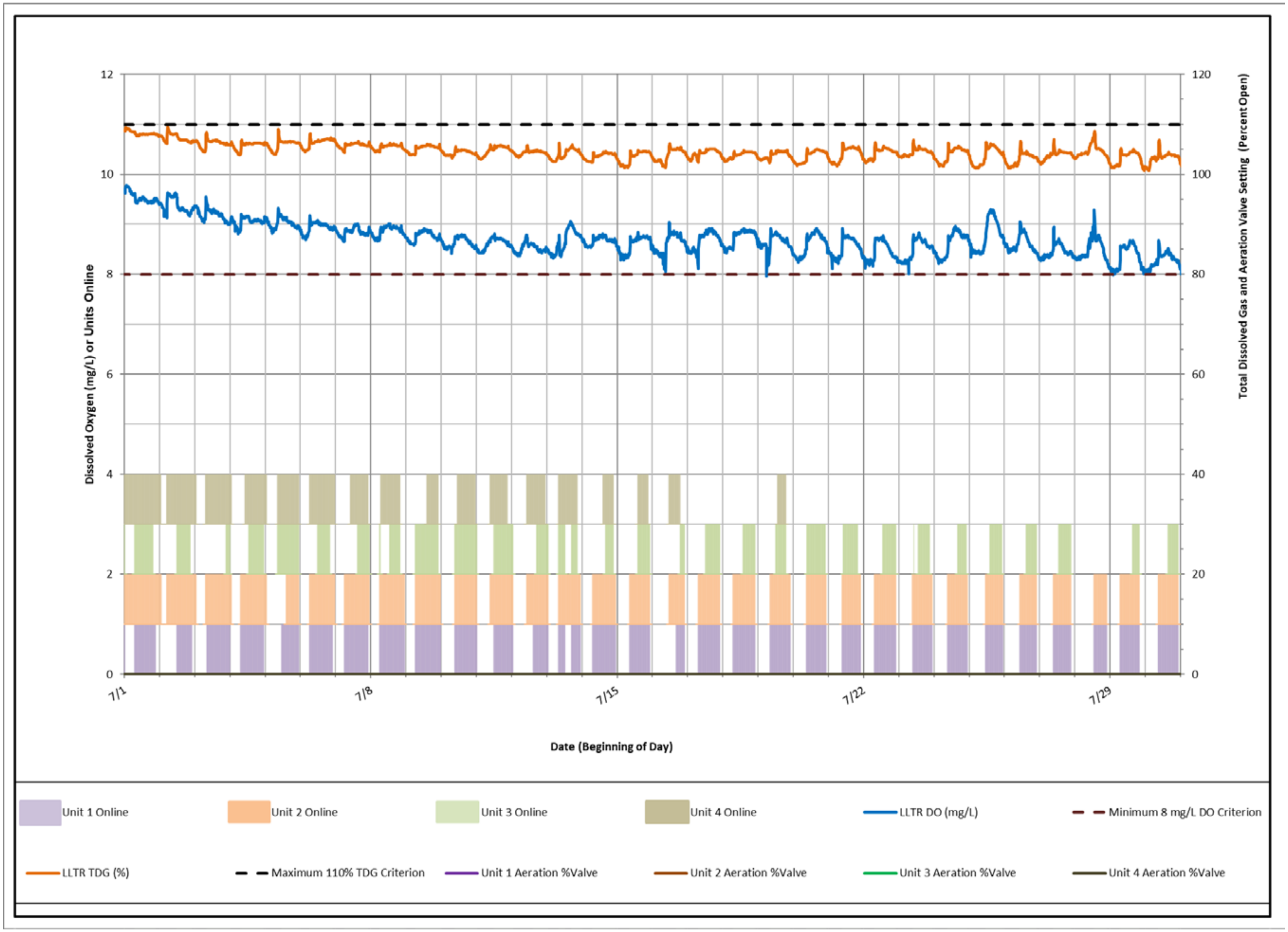


Figure 3-2: LLTR dissolved oxygen (mg/L), total dissolved gas (% of saturation), and operations, July 1 – July 31.

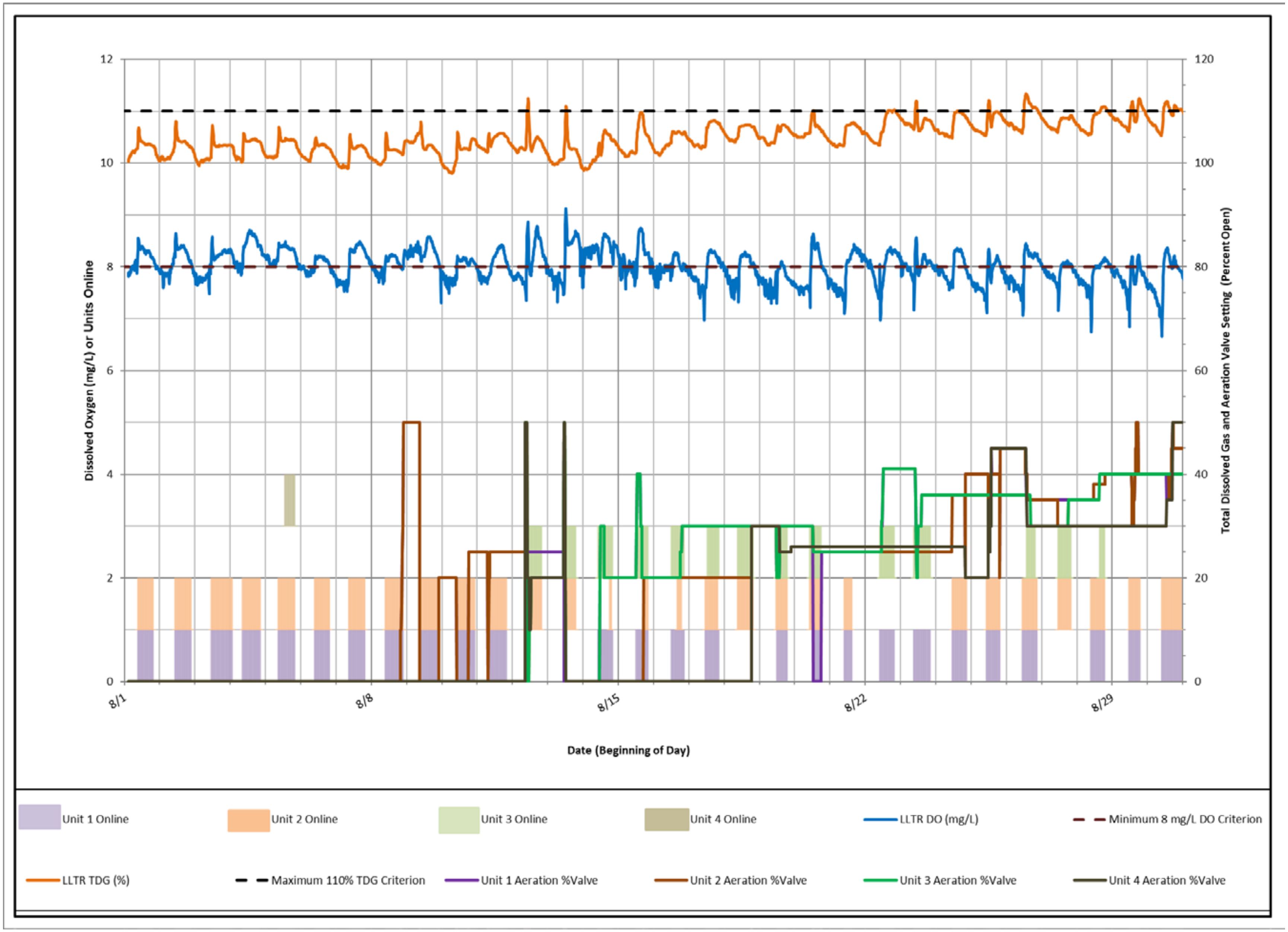


Figure 3-3: LLTR dissolved oxygen (mg/L), total dissolved gas (% of saturation), and operations, August 1 – August 31.

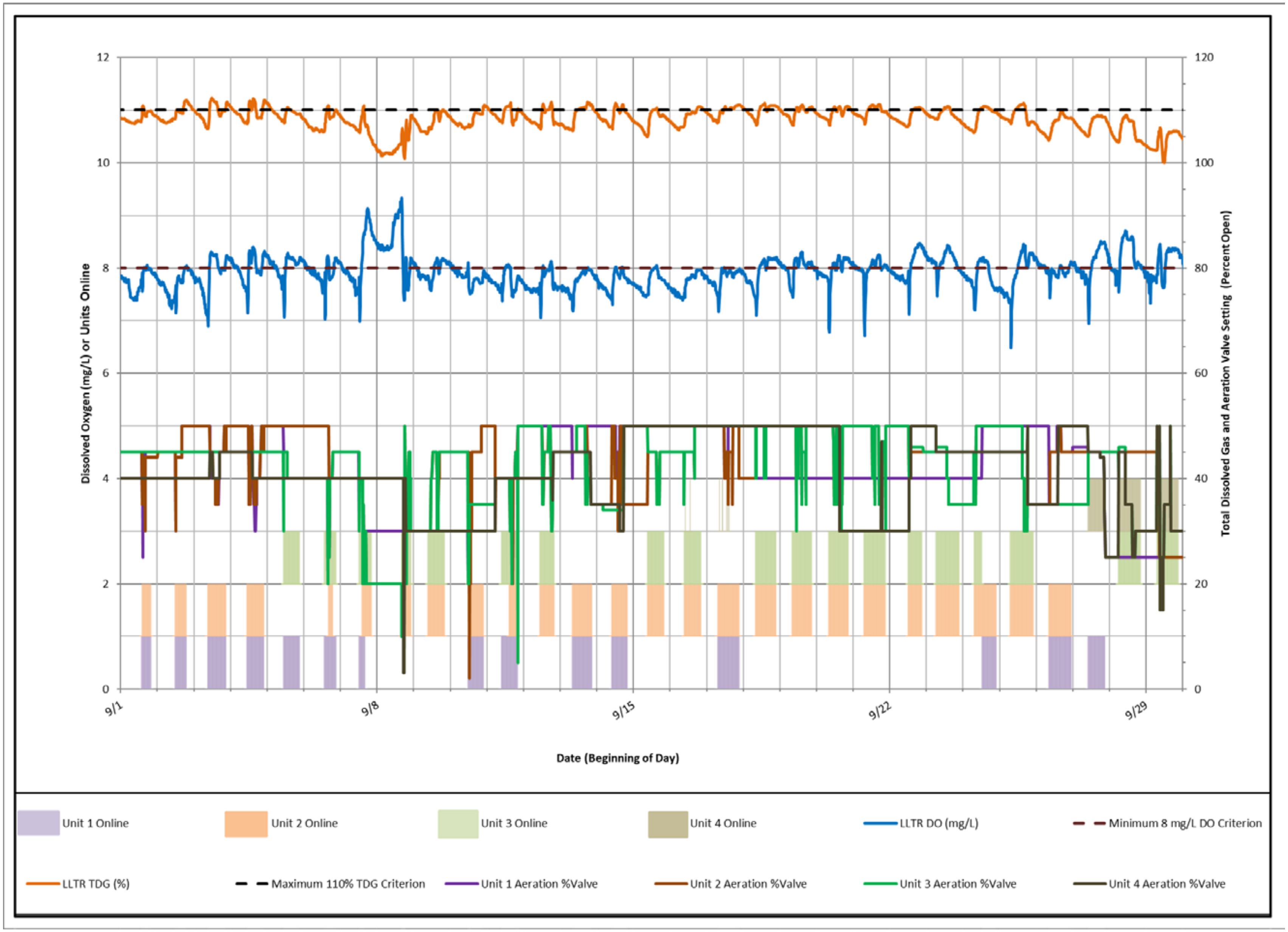


Figure 3-4: LLTR dissolved oxygen (mg/L), total dissolved gas (% of saturation), and operations, September 1 – September 30.

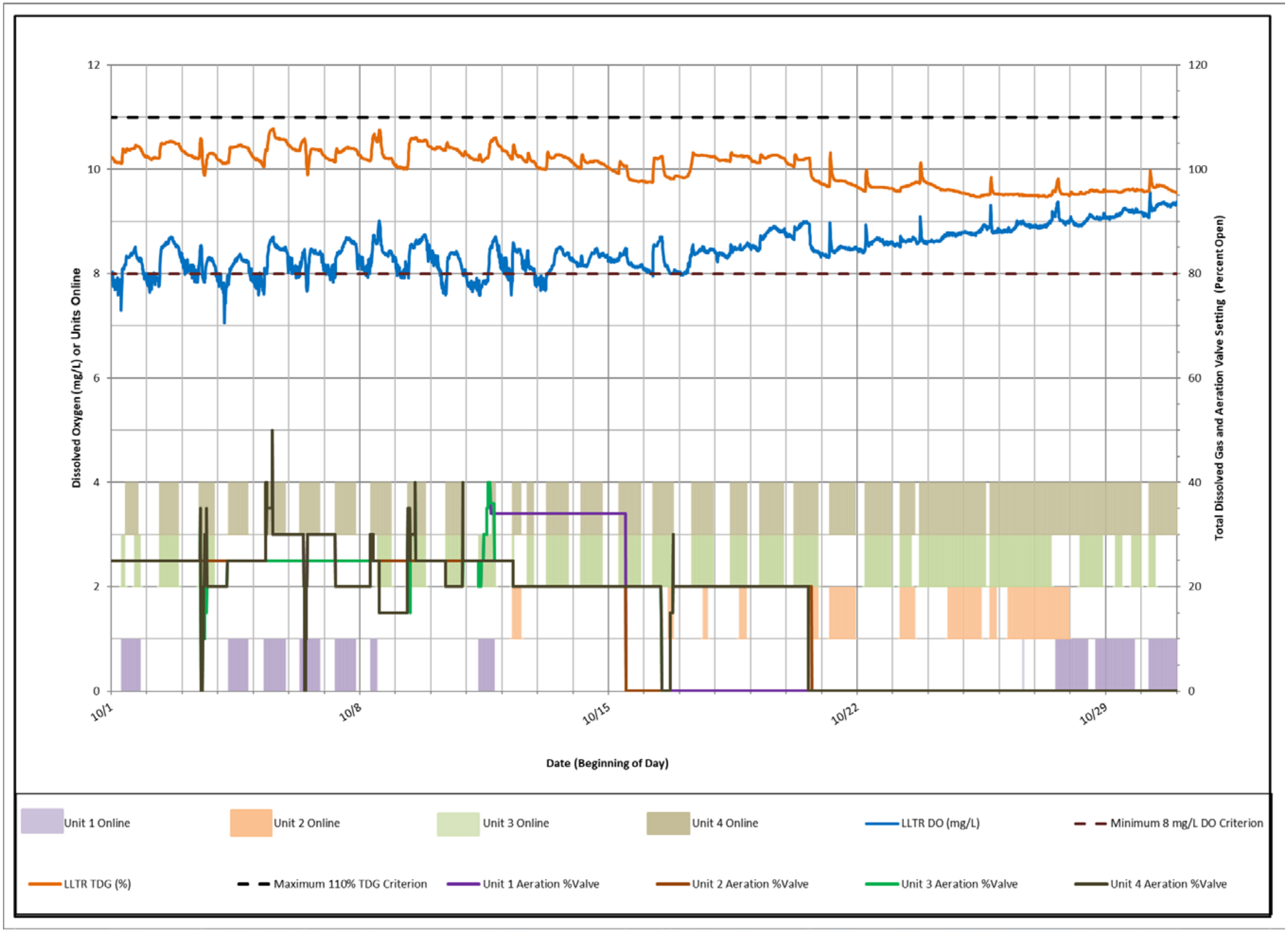


Figure 3-5: LLTR dissolved oxygen (mg/L), total dissolved gas (% of saturation), and operations, October 1 – October 31.

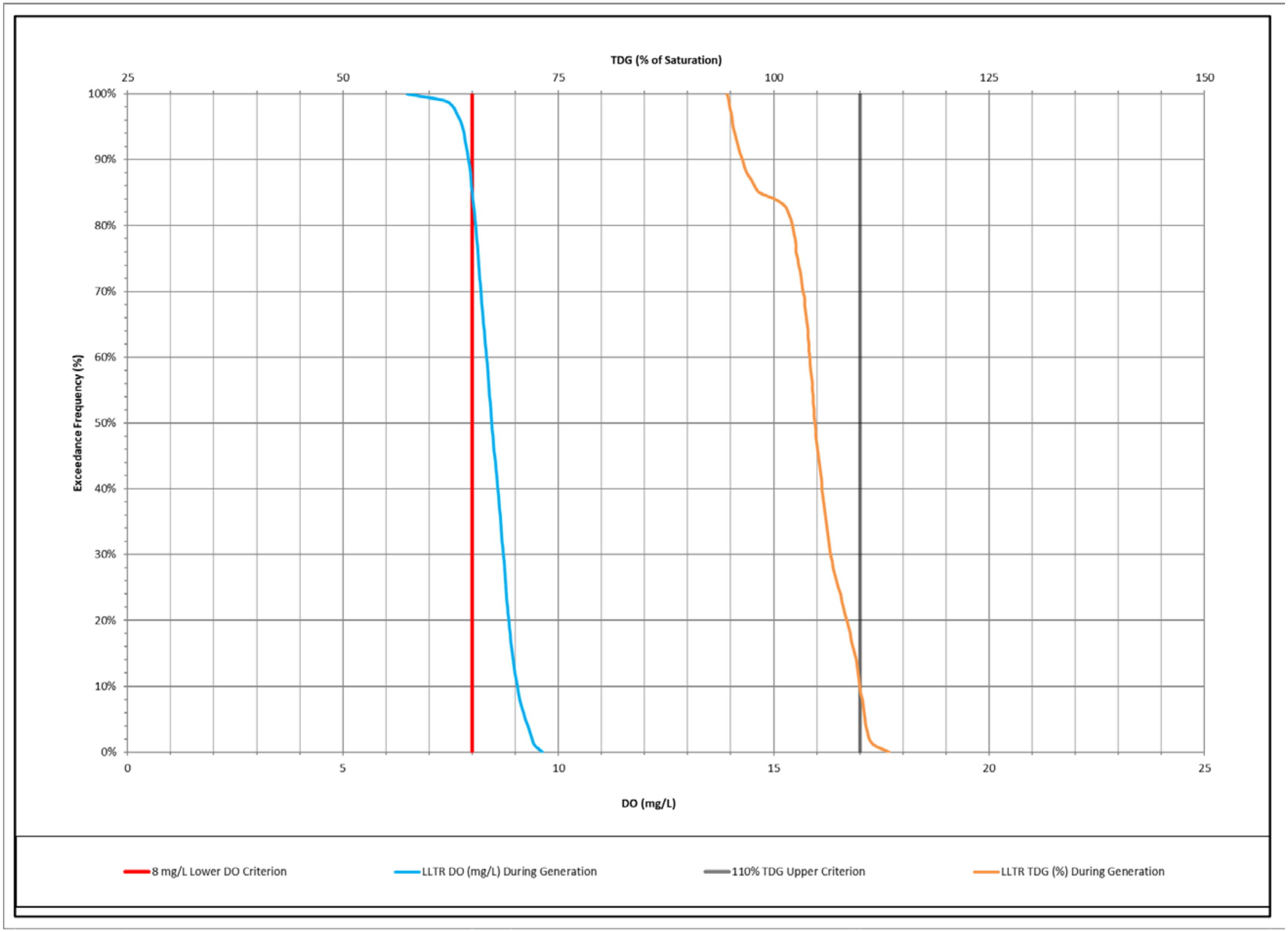


Figure 3-6: LLTR dissolved oxygen (mg/L) concentration and total dissolved gas (% of saturation) exceedance frequency during generation.

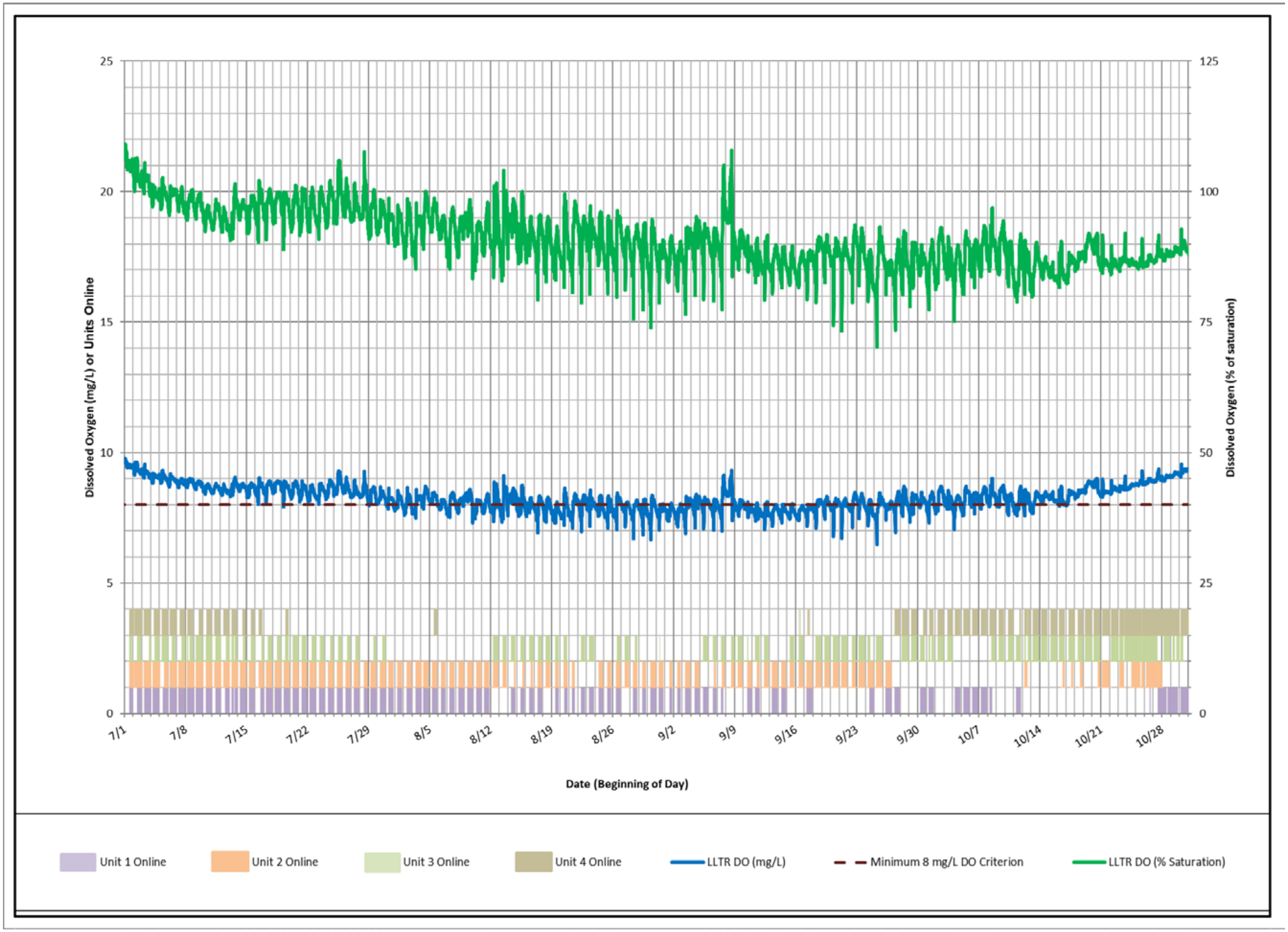


Figure 3-7: LLTR dissolved oxygen concentration (mg/L) and percent of saturation and operations.

Action	Task	2009	2010	2011	2012	2013	2014	2015
Structural Modifications	Phase II – Apply modeling tools to determine alternatives most likely to be effective		S	S	S			
	Phase II – Identify highest priority alternative to be field tested		S					
	Phase II – Prepare Work Plan to test effectiveness of highest priority alternative		S					
	Phase II – Implement Work Plan and prepare summary report		S					
	Phase II – Determine if additional aeration measures are necessary, and prepare/implement corresponding Work Plans for testing effectiveness of additional high priority aeration measures			(S)	(S)			
	Phase III - Construct permanent modifications for preferred alternative			S	S			
	Phase IV - Evaluate need for any additional DO enhancement measures					S	S	
Monitoring	Select/design permanent monitoring stations and develop monitoring plan	M	M					
	Prepare and implement Phase II water quality monitoring plan(s) for testing of high priority alternatives		M	(M)	(M)			
	Monitor DO and other relevant water quality conditions at the 0.6 mile downstream of Long Lake Dam (LLTR)		M	M	M	M	M	
	Annual Monitoring Report			M	M	M	M	
	Five-Year Report							M

Legend

S	Structural
M	Monitoring

() Only done if testing demonstrates need for additional Long Lake HED discharge aeration measures.

Figure 4-1. Approved Long Lake HED DO feasibility and implementation schedule.

APPENDIX A
DATA QUALITY ANALYSIS

DATA QUALITY SUMMARY

Data quality objectives (DQOs) and Measurement Quality Objectives (MQOs) are the quantitative and qualitative terms used to specify how good the data need to be to meet the project's specific monitoring objectives. DQOs for measurement data, also referred to as data quality indicators, include measurement range, accuracy, precision, representativeness, completeness, and comparability. The range, accuracy, and resolution for each measured parameter are provided in Table A-1.

Table A-1. Range, accuracy and resolution of parameters recorded.

Instrument and Parameter	Range	Accuracy	Resolution
MS5 Total Dissolved Gas	400 to 1300 mmHg	±0.1% of span	1.0 mmHg
MS5 Dissolved Oxygen	0 to 30 mg/L	± 0.01 mg/L for 0 to 8 mg/L ± 0.02 mg/L for >8mg/L	0.01 mg/L
MS5 Temperature	-5 to 50°C	±0.10°C	0.01°C
MS5 Depth (0-25 meters)	0 to 25 meters	±0.05 meter	0.01 meter
Barologger Relative Barometric Pressure	1.5 meter of water	± 0.1 cm of water	0.002% of full scale
Barologger Temperature	-10 to 40°C	± 0.05°C	0.003°C

Note: Sources: Hach MS5 User Manual and Solinist Levelogger User Guide [4]

MQOs are the performance or acceptance thresholds or goals for the project's data, based primarily on the data quality indicators precision, bias, and sensitivity. Table A-2 presents MQOs selected during preparation of the Long Lake HED tailrace DO monitoring plan. The meter-specific root mean squared error (RMSE) of the calibration corrections applied after each calibration, and an overall RMSE for all meters compared to MQOs are shown in Table A-3. Table A-4 shows which MS5 was deployed at each monitoring location during the sampling period.

Table A-2. Measurement quality objectives.

Parameter	MQOs
Barometric Pressure	2 mmHg
Temperature	0.5ºC
Total Pressure	1% (5 to 8 mmHg)
TDG%	1%
Dissolved Oxygen	0.5 mg/L

[4] Hach Corporation. 2006. Hydrolab DS5X, DS5, and MS5 Water Quality Multiprobes User Manual. February 2006, Edition 3. Catalog Number 003078HY and Solinist. 2010. Levelogger Series (Levelogger Gold, Barologger Gold, Levelogger Junior, LTC Levelogger Junior and Rainlogger) User Guide - Software Version 3.4.0. August 17, 2010.

Table A-3. Difference between RMSE and MQOs by MS5.
Table Part 1: Barometric Pressure (BAR), Total Pressure, Total Dissolved Gas (TDG)

LLHED TDG Monitoring	RMSE [1]				MQO				RMSE - MQO (positive shaded values denote exceedance of MQO)			
Meter and Site IDs	BAR[2]	Total Pressure[3]	TDG-cal[4]	TDG-spot	BAR	Total Pressure	TDG	TDG	BAR	Total Pressure	TDG-cal	TDG-spot
	mm Hg	%	%	mm Hg	mm Hg	%	%	mmHg	mm Hg	%	%	mm Hg
48763	0.77	0.11	0.11	1.72	2	1	1	5	-1.23	-0.89	-0.89	-3.28
48765	0.77	0.11	0.11	1.72	2	1	1	5	-1.23	-0.89	-0.89	-3.28
Overall RMSE	0.77	0.11	0.11	1.72	2	1	1	5	-1.23	-0.89	-0.89	-3.28

[1] RMSE calculated for each meter during calibration checks while in use and between spot measurements from multiple meters.

[2] RMSE calculated from BAR measured during calibration compared to the TDG in air uncorrected reading.

[3] RMSE calculated as the difference in TDG in air uncorrected measured during calibration minus the BAR, then divided by the TDG and multiplied by 100%.

[4] RMSE calculated as TDG in air uncorrected measured during calibrations divided by the BAR and multiplied by 100%

Table A-3 (Continued). Difference between RMSE and MQOs by MS5
Table Part 2: Temperature and Dissolved Oxygen (DO)

LLHED DO Monitoring	RMSE				MQO		RMSE - MQO (positive shaded values denote exceedance of MQO)			
Meter and Site IDs	Temperature[1]		Dissolved Oxygen[2]		Temp	DO	Temperature[1]		Dissolved Oxygen[2]	
	Calibration	Spot	Calibration	Spot			Calibration	Spot	Calibration	Spot
	°C	°C	mg/L	mg/L	°C	mg/L	°C	°C	mg/L	mg/L
48763	0.06	0.02	0.39	0.05	0.5	0.5	-0.44	-0.48	-0.11	-0.45
48765	0.09	0.02	0.04	0.05	0.5	0.5	-0.41	-0.48	-0.46	-0.45
Overall RMSE	0.08	0.02	0.28	0.05	0.5	0.5	-0.42	-0.48	-0.22	-0.45

[1] For Calibration, RMSE calculated from the difference between the meter and calibration thermometer at all calibration checks while the meter was in use. Spot differences are average differences between measured values from group average.

[2] Calibration RMSE as difference of the calculated pre-calibration and post-calibration measurement. Spot RMSE calculated as average difference between measured values from group average.

N/A - No value reported or not applicable

Root mean squared error (RMSE) = $\sqrt{\frac{\sum_{i=1}^{n}(x_{1,i} - x_{2,i})^2}{n}}$.

Table A-4. ID number, and deployment station and timeframe of MS5s used in 2020.

Deployment Timeframe	LLTR - Primary	LLTR - Secondary
7/1 - 7/7	48765	48763
7/7 - 7/22	48765	48763
7/22 - 8/4	48765	48763
8/4 - 8/19	48765	48763
8/19 - 8/31	48765	48763
8/31 - 9/17	48765	48763
9/17 - 9/29	48765	48763
9/29 - 10/13	48765	48763
10/13 - 10/26	48765	48763
10/26 - 10/31	48765	48763

Measurement Range

The measurement range, range of reliable readings of an instrument or measuring device, specified by the manufacturer is displayed in Table A-1 for each measured parameter. Maintenance of field sampling equipment was conducted in a manner consistent with the corresponding manufacturer's recommendations to provide reliable readings within each instrument's reported measurement range.

Bias

TDG meters, like other field monitoring instruments, are subject to bias due to systematic errors introduced by calibration, equipment hardware or software functioning, or field methods. Bias was minimized by following standard protocols for calibration and maintenance, and by following field protocols for stabilization of meter readings.

Precision

Precision refers to the degree of variability in replicate measurements and is typically defined by the instrument's manufacturer. Manufacturer values for the MS5 and barologger (Table A-1) were within MQOs.

Accuracy

Accuracy is a measure of confidence that describes how close a measurement is to its "true" value (low bias). Throughout this seasonal DO monitoring study, the MS5s underwent calibration and verification procedures.

Instrument accuracy was evaluated through the calibration and maintenance activities along with paired spot measurements (Table A-3). MQOs for all parameters were met for all meters used in the 2020 monitoring season.

Discharge data were obtained from Avista's internal plant control software and is found to be accurate and reliable.

Representativeness

Representativeness qualitatively reflects the extent to which sample data represent a characteristic of actual environmental conditions. For this project, representativeness was addressed through proper design of the sampling program to ensure that the monitoring locations were properly located and sufficient data were collected to characterize DO at that location.

Comparability

Comparability is the degree to which data can be compared directly to previously collected data. Comparability was achieved by consistently monitoring the same downstream long-term monitoring station (LLTR) monitored in the past.

Completeness

Completeness is the comparison between the quantity of data planned to be collected and how much usable data was actually collected, expressed as a percentage (Table A-5). The DO data collection period consisted of 11,808 15-minute periods. All parameters exceeded the goal of 90 percent completeness. Table A-6 summarizes the number of specific DQ Codes applied to LLTR data.

Table A-5. Project completeness.

	LLTR	
	Count	**Completeness (%)**
Monitoring Period	11,808	--
Water Temperature (°C)	11,777	100%
Dissolved Oxygen (mg/L)	11,776	100%
BAR (mm Hg)	11,806	100%
TDG (mm Hg)	11,749	100%
TDG (% of saturation)	11,747	99%
Dissolved Oxygen (% of saturation)	11,774	100%

Table A-6. Number of Specific DQ Codes during the Monitoring Period, July 1 at 0:00 PT through October 31 at 23:45 PT of 2020.

DQ Code	DQ Code Description	LLTR						
		Temp (°C)	TDG (mmHg)	Depth (meters)	DO (mg/L)	Batt (volts)	Level (m H2O)	ATemp (°C)
999	Instrument logging data before deployment at monitoring station	5	5	5	5	5	0	0
998	Out of water after recovery	4	4	4	4	4	0	0
997	Equilibrating after deployment	0	28	0	0	0	0	0
993	Calibration/servicing	22	22	22	22	22	0	0
666	Barometric sensor not at typical location	0	0	0	0	0	2	6
304	Suspect DO value to be inaccurate	0	0	0	1	0	0	0
0	No data qualifiers	11,767	11,739	11,767	11,766	11,767	11,806	11,802
-1002	Corresponds with spot measurement	10	10	10	10	10	0	0
	Monitoring Period[1]	11,808	11,808	11,808	11,808	11,808	11,808	11,808

Notes:

1. Monitoring period was from July 1, 2020 at 0:00 PT to October 31, 2020 at 23:45 PT.
2. Mass verifications were conducted on June 26, 2020.

APPENDIX B

CONSULTATION RECORD

1411 East Mission Avenue
PO Box 3727
Spokane, WA 99220-3727

February 26, 2021

Jordan Bauer, Hydropower Compliance Coordinator
Washington Department of Ecology
Eastern Regional Office
4601 N Monroe Street
Spokane, WA 99205-1295

Subject: Federal Energy Regulatory Commission's Spokane River Hydroelectric Project License, Appendix B, Sections 5.4 and 5.6.B, TDG and DO Reporting Requirements

Dear Jordan:

Ordering Paragraph E of the Federal Energy Regulatory Commission (FERC) Spokane River Hydroelectric Project License incorporated the Washington Department of Ecology (Ecology) Certification Conditions under Section 401 of the Federal Clean Water Act Water Quality Certification (Certification) as Appendix B of the License. Per Sections 5.4 and 5.6.B of the Certification, Avista is submitting the following project status and reports for your review and approval.

Section 5.4: Total Dissolved Gas
There are two components related to Total Dissolved Gas (TDG), which include the following:

- *2020 Long Lake Total Dissolved Gas Monitoring Report*
  Avista completed the Long Lake Dam Spillway Modification Project in December 2016. Following completion of the project, Avista monitored TDG to assess the effectiveness of the modifications and to evaluate spillgate operational protocols. In 2020, Ecology approved Avista's plans to conduct an additional three years on effectiveness monitoring (2020 – 2022) and reporting (2021 – 2023). The enclosed 2020 Long Lake TDG Monitoring Report provides the results the TDG monitoring completed during 2020.

  Avista plans to monitor TDG in 2021 and will work with Ecology to evaluate Long Lake HED's compliance to the requirements of the License.

- *2020 Nine Mile HED Total Dissolved Gas Monitoring Report*
  In February 2012, Ecology approved Avista's request to delay the required TDG monitoring at Nine Mile Dam until Avista completed the turbine units 1 and 2 replacement project and the sediment bypass system upgrade and associated intake deck and trashrack cleaning system. Ecology required TDG monitoring for two years, resuming the first season following the completion of these projects, when flows occur during the 7Q10 median flow of 25,400 cfs or higher at the Spokane gage (USGS 12422500). In 2019, Avista completed one year of TDG monitoring following the completion of these projects.

In 2020, discharge flows at the Spokane gage reached a maximum of 19,400 cfs and did not get near the 7Q10 flows, therefore TDG monitoring was not applicable. Avista plans to monitor TDG in 2021 assuming snowpack and runoff forecasts results in flows reaching the 7Q10 flow to fulfill the second year of required monitoring.

Section 5.6.B: Dissolved Oxygen

The enclosed 2020 Long Lake HED Tailrace Dissolved Oxygen (DO) Monitoring Report (LL DO Report) provides the results of the 2020 DO monitoring immediately downstream of Long Lake Dam for the low-flow period of the year and summarizes the use of draft tube aeration to increase DO levels in the river below the dam's tailrace. Avista plans to continue with the aeration program in 2021 and continue monitoring DO and TDG at the Long Lake Dam Tailrace Station.

Attached, please find the LL TDG Report and the LL DO Report for Ecology's review and approval. We would like to receive any comments or recommendations that you may have by March 31, 2021, which will allow us time to file the Report with FERC by April 15, 2021.

Please feel free to contact me at (509) 495-4084 or Meghan Lunney at (509) 495-4643 if you have any questions or wish to discuss the report.

Sincerely,

Chris Moan
Fisheries Habitat Biologist

Enclosures (2)

cc: Brian Crossley, Ecology
Meghan Lunney, Avista

STATE OF WASHINGTON

DEPARTMENT OF ECOLOGY

4601 N. Monroe Street • Spokane, Washington 99205-1295 • (509) 329-3400

March 24, 2021

Chris Moan
Avista Corp.
1411 East Mission Avenue
PO Box 3727
Spokane, WA 99220

RE: Request for Ecology Review and Approval – Avista 2020 Long Lake Tailrace HED Dissolved Oxygen and Total Dissolved Gas Monitoring Reports – Spokane River FERC Project No. 2545

Dear Chris Moan:

The Department of Ecology (Ecology) has reviewed Avista's submittal of the "2020 Long Lake HED Tailrace Dissolved Oxygen Monitoring Report" and "2020 Long Lake Total Dissolved Gas Monitoring Report." These reports were received by Ecology on February 26, 2021, via email. The reports were completed in accordance with Sections 5.4(D) and 5.6(B) of Ecology's 401 Certification (Certification) and consistent with Spokane River Hydroelectric Project No. 2545 (License) Appendix B.

The critical period of standard exceedance for both dissolved oxygen (DO) and total dissolved gas (TDG) appears to occur late August until the end of the September. It would be helpful to provide language discussing the tradeoff between aeration vs TDG increases during that time. It is not clear in the discussion to what extent aeration is impacting the elevated TDG levels during use. However, perhaps additional monitoring is needed to provide more information on this during times of standard exceedance.

Otherwise, Ecology has no additional comments and **APPROVES** the 2020 Long Lake HED Dissolved Oxygen and Total Dissolved Gas Monitoring Reports.

Please contact me with any questions at (509) 688-9403 or jordan.bauer@ecy.wa.gov.

Sincerely,

Jordan Bauer
Hydropower Compliance Coordinator
Water Quality Program

JB:red

cc: Meghan Lunney, Avista
Monica Ott, Avista
Brian Crossley, Spokane Tribe
Chad Atkins, Ecology

ECOLOGY COMMENTS AND AVISTA RESPONSES

Ecology Comment

The critical period of standard exceedances for both dissolved oxygen (DO) and total dissolved gas (TDG) appears to occur late in August until the end of September. It would be helpful to provide language discussing the tradeoff between aeration vs TDG increases during that time. It is not clear in the discussion to what extent aeration is impacting the elevated TDG levels during use. However, perhaps additional monitoring is needed to provide more information on this during times of standard exceedance.

Avista Response

The 2020 results indicate that during late August through September the effort to get DO above 8.0 mg/L frequently resulted in TDG values slightly above 110%, with a maximum of 113.4% (which occurred on August 26). Sections 2.2, 3.6, and 4.1 provide general statements pertaining to the tradeoff that occurs during aeration where adding air to the water not only increases DO but increases the saturation of all gasses in the water, resulting in increased total dissolved gas.

The magnitude aeration has on increased TDG has not been quantified by Avista, instead analysis has focused on finetuning aeration operations in order to increase DO to 8.0 mg/L, but not cause an exceedance in TDG levels. Limited data from 2020 suggest aeration can increase TDG by 2.1% over 2.5 hours when the aeration valves are open 25% on two units; 2.0% over 9 hours when the aeration valves are open 25% on two units; and 6.7% over 1.5 hours when the aeration valves are open 50% on 2 units.

The magnitude of the impacts of aeration would be dependent on water characteristics at the time of aeration. The concentration of DO in water is mainly regulated by photosynthesis, atmospheric diffusion and biologic respiration. The concentration of DO in water is also influenced by temperature, pressure and other chemical reactions (such as oxidation and reduction). The maximum amount of oxygen that can be dissolved in water is termed the “saturation” concentration. Saturation is reached when no additional oxygen can be dissolved in water with the saturation concentration changes based on ambient pressure and temperature. The amount of oxygen that can be dissolved in water decreases at higher temperatures and increases at higher pressure (for example, more oxygen can be dissolved in water at sea level than at higher elevations). Therefore, determining the exact magnitude that aeration is having on water passing through the dam could be highly variable based on seasonal and site-specific upstream conditions.

Avista looks forward to further discussing how these environmental conditions impact aeration operations, including DO and TDG values, with Ecology.

Ecology Comment

Otherwise, Ecology has no additional comments and **APPROVES** the 2020 Long Lake HED Dissolved Oxygen and Total Dissolved Gas Monitoring Reports.

Avista Response

Avista appreciates Ecology’s review and approval of the 2020 Long Lake HED Tailrace Dissolved Oxygen Monitoring Report.

AVISTA
1411 East Mission Avenue
PO Box 3727
Spokane, WA 99220-3727

February 26, 2021

Brian Crossley
Water & Fish Program Manager
Spokane Tribe Natural Resources
P.O. Box 480
Wellpinit, WA 99040

Subject: Federal Energy Regulatory Commission's Spokane River Hydroelectric Project License, Appendix B, Sections 5.4 and 5.6.B, TDG and DO Reporting Requirements

Dear Brian:

Ordering Paragraph E of the Federal Energy Regulatory Commission (FERC) Spokane River Hydroelectric Project License incorporated the Washington Department of Ecology (Ecology) Certification Conditions under Section 401 of the Federal Clean Water Act Water Quality Certification (Certification) as Appendix B of the License. Per Sections 5.4 and 5.6.B of the Certification, and the October 2008 Settlement Agreement between Avista and the Spokane Tribe, Avista is submitting the following project status and reports for your review and comment.

Section 5.4: Total Dissolved Gas
There are two components related to Total Dissolved Gas (TDG), which include the following:

- *2020 Long Lake Total Dissolved Gas Monitoring Report*
  Avista completed the Long Lake Dam Spillway Modification Project in December 2016. Following completion of the project, Avista monitored TDG to assess the effectiveness of the modifications and to evaluate spillgate operational protocols. In 2020, Ecology approved Avista's plans to conduct an additional three years on effectiveness monitoring (2020 – 2022) and reporting (2021 – 2023). The enclosed 2020 Long Lake TDG Monitoring Report provides the results the TDG monitoring completed during 2020.

  Avista plans to monitor TDG in 2021 and will work with Ecology to evaluate Long Lake HED's compliance to the requirements of the License.

- *2020 Nine Mile HED Total Dissolved Gas Monitoring Report*
  In February 2012, Ecology approved Avista's request to delay the required TDG monitoring at Nine Mile Dam until Avista completed the turbine units 1 and 2 replacement project and the sediment bypass system upgrade and associated intake deck and trashrack cleaning system. Ecology required TDG monitoring for two years, resuming the first season following the completion of these projects, when flows occur during the 7Q10 median flow of 25,400 cfs or higher at the Spokane gage (USGS 12422500). In 2019, Avista completed one year of TDG monitoring following the completion of these projects.

> In 2020, discharge flows at the Spokane gage reached a maximum of 19,400 cfs and did not get near the 7Q10 flows, therefore TDG monitoring was not applicable. Avista plans to monitor TDG in 2021 assuming snowpack and runoff forecasts results in flows reaching the 7Q10 flow to fulfill the second year of required monitoring.

Section 5.6.B: Dissolved Oxygen
The enclosed 2020 Long Lake HED Tailrace Dissolved Oxygen (DO) Monitoring Report (LL DO Report) provides the results of the 2020 DO monitoring immediately downstream of Long Lake Dam for the low-flow period of the year and summarizes the use of draft tube aeration to increase DO levels in the river below the dam's tailrace. Avista plans to continue with the aeration program in 2021 and continue monitoring DO and TDG at the Long Lake Dam Tailrace Station.

Attached, please find the LL TDG Report and the LL DO Report for the Spokane Tribe's review and comment. We would like to receive any comments or recommendations that you may have by **March 31, 2021**, which will allow us time to file the Report with FERC by April 15, 2021.

Please feel free to contact me at (509) 495-4084 or Meghan Lunney at (509) 495-4643 if you have any questions or wish to discuss the report.

Sincerely,

Chris Moan
Fisheries Habitat Biologist

Enclosures (2)

cc: Jordan Bauer, Ecology
Meghan Lunney, Avista

Spokane Tribal Natural Resources
PO BOX 480 • Wellpinit, WA 99040 • (509) 258-9042 • fax 258-9600

MEMORANDUM

TO: Chris Moan; Avista Corp.

FROM: Casey Flanagan, Water & Fish Program

SUBJECT: Spokane Tribe Review of Avista 2020 DO, Temperature and TDG Reports

DATE: March 31, 2021

Dear Chris Moan,

The Spokane Tribe of Indians has reviewed Avista's 2020 Long Lake HED Tailrace Dissolved Oxygen Monitoring Report, the 2020 Long Lake Total Dissolved Gas Monitoring Report and the 2020 Long Lake HED Temperature Monitoring Report.

In regards to the Dissolved Oxygen Monitoring Report, the Tribe is optimistic by Avista meeting 8.0mg/L standard 88.8% of the time during generation. We also observed that dissolved oxygen standards were met 57.2% of the time during non-generation. We encourage Avista to look at aeration during non-generation in order to meet the dissolved oxygen standard throughout 24-hour periods in the summer months. We noticed that dissolved oxygen standards were met after Mid-September, but the dam continued to aerate until October 20th; a brief explanation of why that happened would be beneficial to the report.

When reviewing the Total Dissolved Gas Monitoring Report, the Tribe is encouraged to see improvements in TDG due to spillway deflectors installed on Long Lake Dam in 2016. The report shows that TDG concentrations are still above the 110% standard even when the Spokane River flows are below the 7Q10, with 2020 maximum TDG being 114.6% at LLTR. The Tribe recommends Avista to study reducing TDG through gate operations specifically when flows are greater than or equal to 11,000cfs.

The Tribe recognizes in the Lake Spokane Temperature Report that Lake Spokane continues to have issues with temperature in the epilimnion while also having issues with dissolved oxygen in the hypolimnion in the summer and fall months. This can limit available summer habitat to cold water species in Lake Spokane, as well as downstream of Long Lake Dam on Spokane Indian Reservation waters. The Tribe is interested in reading the report regarding habitat utilization of cold-water species in Lake Spokane. We suggest that the habitat utilization report be included in the appendices or be referenced heavily within the discussion of the temperature report to allow readers to understand Avista's biological optimization justification of Lake Spokane.

If you have any questions regarding the Spokane Tribe's comments, please contact Brian Crossley or Casey Flanagan with the Spokane Tribe's Water and Fish Program.

Sincerely,

C. Flanagan

Casey Flanagan
Water and Fish Project Manager
caseyf@spokanetribe.com

cc: Brent Nichols, Fisheries and Water Division Manager
Brian Crossley, Water & Fish Program Manager
Jordan Bauer, Dept. of Ecology
BJ Kieffer, Director Dept. of Natural Resources
Danny Kieffer, Spokane Tribal Council

SPOKANE TRIBE COMMENTS AND AVISTA RESPONSES

Spokane Tribe Comment
In regards to the Dissolved Oxygen Monitoring Report, the Tribe is optimistic by Avista meeting the 8.0 mg/L standard 88.8% of the time during generation. We also observed that dissolved oxygen standards were met 57.2% of the time during non-generation. We encourage Avista to look at aeration during non-generation in order to meet the dissolved oxygen standard throughout 24-hour periods in the summer months.

Avista Response
Avista does not have the operational ability to aerate during non-generation times. In June 2006, Avista completed the Final Report Long Lake Hydroelectric Development Phase 1 Aeration Study, where alternative aeration options were evaluated for effectiveness and cost. The alternative chosen provided Avista the greatest ability to directly control the amount of oxygen into the water, therefore maximizing the impact aeration can have on water passing downstream of the dam.

LLTR's minimum DO concentration for non-generation periods was 7.0 mg/L, which occurred in mid-September of 2020, and coincided with low incoming DO levels. Avista looks forward to working with the Spokane Tribe to compare DO data that the Spokane Tribe may have collected to better understand aeration impacts during generation and non-generation timeframes in the river downstream of LLTR.

Spokane Tribe Comment
We noticed that dissolved oxygen standards were met after Mid-September, but the dam continued to aerate until October 20th; a brief explanation of why that happened would be beneficial to the report.

Avista Response
Dissolved oxygen at LLTR last fell below the 8.0 mg/L standard on October 17 (Figure 3-5). From that point, aeration continued until mid-day on October 20th, which was when Avista was confident DO values would no longer fall below 8.0 mg/L. TDG values did not exceed 110% during this timeframe, indicating that aeration during this time did not have a negative impact on water quality.