TOTAL DISSOLVED GAS MATRIX MONITORING STUDY PLAN
BOX CANYON HYDROELECTRIC PROJECT
(FERC NO. 2042)

Public Utility District No. 1 of Pend Oreille County
130 N. Washington
Newport, WA 99156

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1.0 INTRODUCTION

The Federal Energy Regulatory Commission (FERC) issued a license to Public Utility District No. 1 of Pend Oreille County (District) for the operation of Box Canyon Hydroelectric Project (FERC No. 2042) on July 11, 2005. One of the 4(e) license conditions mandated by the U.S. Department of Interior stipulated that the District must monitor Total Dissolved Gas (TDG) levels in the tailrace using automated instruments arranged in a spatial pattern adequate to quantify TDG levels through the TDG mixing zone, describing spatial and temporal variation in TDG exchange processes in relation to Project operations.

This study plan describes the methods to be used for a study to be conducted in spring 2019 to investigate the distribution of TDG levels downstream of Box Canyon Dam.

2.0 STUDY OBJECTIVES

The primary objective of this study is to describe the TDG levels and distribution patterns downstream of Box Canyon Dam. A previous study done in 2006 (EES 2007) had indicated that strong lateral TDG gradients exist during periods of spill at Box Canyon Dam due to the difference in TDG levels between powerhouse flow and spill flow. This previous study indicated that complete mixing of the turbine and spill flows did not occur until approximately 5 miles downstream.

As part of its compliance efforts, the District has completed upgrading of the project turbines, which was one of the major activities planned under the Total Dissolved Gas Abatement Plan for the Project. The turbine upgrades increase generator capacity at the dam, thereby reducing the spill necessary at those times when spill increases TDG levels the most. Spill gate lift modifications have also been completed, which allow gates to be lifted from lower in the water column such that spill is converted from a plunging effect to a skimming effect, thus reducing TDG entrainment. As a result, the current study is being conducted to document TDG levels and distribution compared to those that existed prior to these efforts to reduce TDG entrainment.

3.0 EXISTING INFORMATION

As previously noted, the 2006 TDG study (EES 2007) suggested that complete TDG mixing did not occur until approximately 5 miles downstream of the Box Canyon Dam spillway. Annual TDG monitoring from 2008 to 2015 has also shown that TDG increases below the spillway approximately 10% for every 10,000cfs of spill flow, up to a spill flow of approximately 40,000cfs. As spill increases above 40,000cfs, the contribution to TDG decreases, because the spill gates are progressively opened as flow increases. As a result, project head is lowered until only the bottom spill gate leaves remain, which are completely submerged at 80,000cfs. Preliminary results from regular TDG monitoring in 2016 and 2017 (District 2016, 2017) suggest that TDG increases in spill flow may be substantially reduced with the recently completed TDG reduction efforts.

4.0 METHODS

4.1 Instrumentation

Hydrolab water quality monitoring instruments equipped with TDG, temperature, and depth sensors will be used to record data at 30-minute intervals (on the hour and half hour). The instruments will record date, time, TDG pressure (mmHg), depth (ft), and water temperature (°C). Instrument battery voltage (V) will also be recorded.

Instrument deployment methods for the tailwater monitoring locations will be determined either by the District or by a contractor hired by the District. In any case, the instruments will be consistently located over the period of the study. As part of the normal annual water quality monitoring, an instrument will be deployed in the forebay in a perforated standpipe located to the side of the upstream side of the spill gates. The forebay TDG instrument will be deployed at an elevation of approximately 2,015 ft, or about 15 ft below a typical operating water surface elevation of 2,028 ft.

Six Hydrolab instruments capable of logging time histories of TDG pressures will be utilized at locations in the tailwater area of Box Canyon Dam. At each of three river mile (RM) locations, two instruments will be deployed – one located toward river left and one toward river right. All instruments will be located below a minimum depth of 10 ft, which is approximately the minimum compensation depth that avoids false data due to air bubbles being trapped on the sensor membrane. Previous studies documented that no vertical TDG gradient exists in the tailrace. The proposed approximate locations of instruments are shown in Table 1 and Figure 1; precise locations will be determined once the anchoring and deployment configurations are completely determined. Once these locations are determined, a Garmin handheld GPS receiver will be used to record instrument locations to within a few feet.

Table 1. Hydrolab Locations

Instrument	Approximate RM
FB	34.6
Tail_1	33.8
Tail_2	32.2
Tail_3	30.9

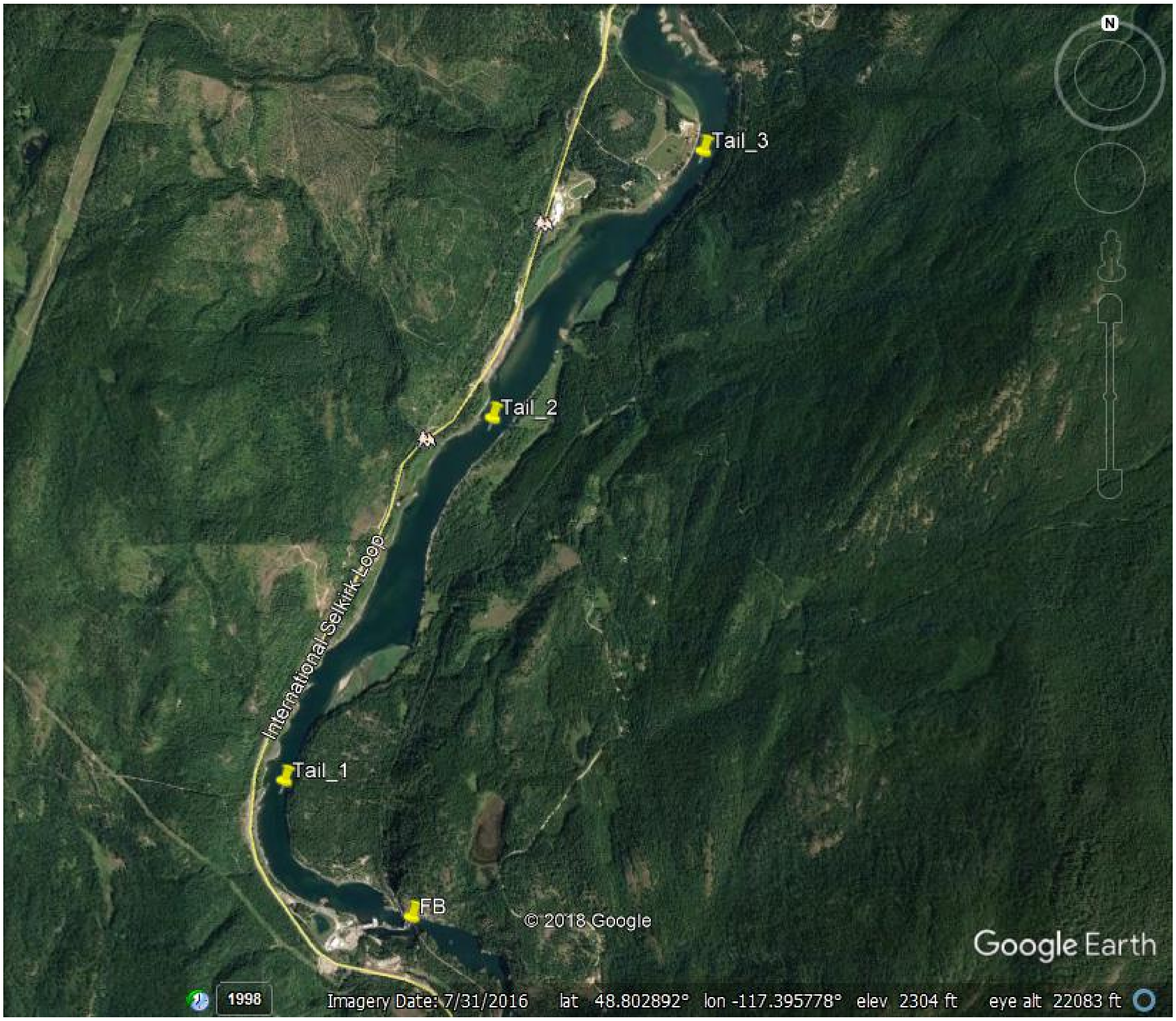

Figure 1. Locations of TDG monitoring instruments in Box Canyon forebay and tailrace.

4.2 Barometric Pressure

Barometric pressure is necessary to compute the TDG percent saturation in water relative to atmospheric pressure. The District operates a continuous recording climate station at Box Canyon Dam, which includes the recording of barometric pressure. A hand held digital barometer will be used to verify the climate station barometric pressure each time the instruments are serviced.

4.3 Calibration and Maintenance

Instruments will be calibrated prior to deployment and checked again upon retrieval according to the manufacturer's specifications. Instrument calibration procedures are summarized in Appendix A. Data will be downloaded and instruments serviced approximately every 3 weeks. At each servicing, trained personnel will: 1) download the data recorded by the instrument, 2) check that calibrations remain within QA/QC criteria, 3) recalibrate parameters if necessary, and

4) check for and if necessary remedy site problems such as clogged probes, failed membranes, etc.

Monitoring will begin the first week of April 2019. TDG monitoring in the tailrace will extend through the end of June 2019, or until the spill season is over, whichever occurs first. Monitoring at the forebay location and the Tail_1 river right location will continue through October according to the annual water quality monitoring plan as specified in the Box Canyon license.

4.4 Discharge and Spill

Hourly discharge and spill measurements for Box Canyon Hydroelectric Project will be obtained from District records.

4.5 Spill Gate Variations

In order to test various spill gate configurations to determine which combination(s) result in minimum increases in TDG, the spill gates will be manipulated in several combinations to determine the effects on TDG levels and distribution. However, travel time for a parcel of water must also be taken into account when comparing downstream monitoring locations back to the TDG in the forebay. Previous studies (EES 2007) suggest that it takes approximately 2 hours equilibration time from the spillway to the Tail_3 location. Therefore, a given spill gate test configuration will be maintained for a minimum of 8 hours to ensure sufficient data is gathered for valid assessment. Table 2 shows the proposed river flow and gate configuration tests to be performed. Exact timing of these tests will depend on timing of spring runoff.

Table 2. Spill Gate Test Variations

Test #	Target range for total spill flow (cfs)	Proportion of Spill Flow			
		Gate 1	Gate 2	Gate 3	Gate 4
1	10,000 ± 5,000	¼	¼	¼	¼
2	10,000 ± 5,000	0	0	½	½
3	10,000 ± 5,000	½	½	0	0
4	10,000 ± 5,000	0	1/3	1/3	1/3
5	10,000 ± 5,000	1/3	1/3	1/3	0
6	25,000 ± 5,000	¼	¼	¼	¼
7	25,000 ± 5,000	0	0	½	½
8	25,000 ± 5,000	½	½	0	0
9	25,000 ± 5,000	0	1/3	1/3	1/3
10	25,000 ± 5,000	1/3	1/3	1/3	0

4.6 Reporting

All data will be coordinated in Excel spreadsheets, and TDG time sequences plotted on appropriate graphs. Comparisons will be made between the forebay TDG and each tailrace monitoring location, as well as between tailrace locations at the same river mile. Comparisons will also be made between the various spill gate configuration tests to ascertain the best gate configurations for future operations. A comprehensive report will be drafted summarizing all of the results.

5.0 SCHEDULE

Task	Completion
Approved study plan	Jan. 25, 2019
Distribute bid for contracts	Feb. 15, 2019
Contractor hired	March 1, 2019
Determine anchoring and place anchors in river	March 29, 2019
Deploy instruments	April 5, 2019
Remove instruments	June 28, 2019
Coordinate all collected data	August 30, 2019
Draft report	Nov. 1, 2019
Final report	Dec. 31, 2019

6.0 REFERENCES

EES Consulting. 2007. Total dissolved gas grid monitoring report. Prepared for Public Utility District No. 1 of Pend Oreille County. Newport, WA. July, 2007.

Pend Oreille Public Utility District No. 1. 2016. Water quality monitoring 2016 annual report. Newport, WA. December, 2016.

Pend Oreille Public Utility District No. 1. 2017. Water quality monitoring 2017 annual report. Newport, WA. December, 2017.

APPENDIX A

QA/QC AND CALIBRATION PROCEDURES FOR HYDROLAB DATASONDE™

QA/QC and Calibration Procedures for Hydrolab DataSonde™

Calibration

Total Dissolved Gas

1. Perform a three-point calibration. Determine local barometric pressure. A secondary source - i.e., common sensing unit that has been calibrated to an accurate barometer - may be used.
2. Calibrate ambient pressure: barometric pressure = total dissolved gas pressure (units = mmHg). On instrument calibration menu, enter the barometric pressure.
3. Set up TDG probe to pressure source (TDG membrane must be removed). Add 100mmHg of pressure. (Note: 100mmHg is equal to approximately 114% saturation). On instrument calibration menu, enter barometric pressure plus 100mmHg. Add another 100mmHg of pressure (total of 200mmHg above atmospheric). On instrument calibration menu, enter barometric pressure plus 200mmHg. At all three points, instrument reading should be within ±3mmHg of the expected value.
4. Check for leaks. Dip probe into a solution of seltzer water. Readings should climb rapidly to at least 900-1000 mm Hg (within approximately 60 seconds). If probe does not respond or responds slowly, there is a leak in the membrane. Membrane needs to be replaced.

Dissolved Oxygen - Luminescent DO

1. Determine local barometric pressure. A secondary source - i.e., common sensing unit that has been calibrated to an accurate barometer - may be used.
2. Rinse dissolved oxygen probe.
3. Pour water into calibration cup (Hydrolab should be inverted) to cover the temperature sensor, but not so far as to cover the LDO sensor with water. Cover calibration cup tightly with lid, and shake to saturate the air in the calibration cup.
4. Unscrew lid and lightly cover the calibration cup with lid, and allow the current DO value and temperature readings to stabilize (approximately 1-2 minutes). Enter the current absolute barometric pressure in mmHg and calibrate. Upon completion, DO reading on instrument should be within ±5% of 100%.

pH

1. Use pH=7 and pH=10 for a 2-point calibration check. (Note: changes in temperature will change pH by 0.01-0.10).
2. Go to instrument calibration menu. Starting with pH=7, submerge probes in buffer solution. Allow to equilibrate. Note pH reading and compare to expected pH value (compensating for temperature as needed). If pH reading is within 0.1 unit of the expected pH value, proceed to step 3. If pH reading is not within 0.1 unit of the expected pH value, proceed to step 4.
3. Going to pH=10, submerge probes in buffer solution. Allow to equilibrate. Note pH reading and compare to expected pH value (compensating for temperature as needed). If pH reading is within 0.1 unit of the expected pH value, record readings at both pH values; calibration procedure is complete at this point.
4. The top surface of the reference electrode contains a “Teflon junction” which allows for the pH reference solution to escape. Do not handle by this Teflon junction.

5. Unscrew the Teflon cap from the pH sensor. Rinse pH sensor cavity with distilled water. Drop 1 salt tablet into sensor cavity. Refill cavity with new pH reference solution. Fill almost to the top of the probe and gently replace cap onto pH sensor. The excess reference solution will leak out the side/top of the sensor as the cap is screwed on and tightened.
6. Use pH=7 and pH=10 for a 2-point calibration. (Note: changes in temperature will change pH by 0.01-0.10).
7. Go to instrument calibration menu. Starting with pH=7, submerge probes in buffer solution. Allow to equilibrate. Enter in calibration value, compensating for temperature as needed.
8. Repeat step 7 to calibrate with pH=10 solution.

<u>Turbidity</u>

1. Perform a 2-point calibration.
2. Fill calibration cup with first turbidity standard. Allow solution to settle out until any air bubbles have dissipated.
3. Note turbidity reading and compare to expected value. If turbidity reading is within 1 NTU of the expected value, proceed to step 4. If turbidity reading is not within 1 NTU of expected value, proceed to step 6.
4. Fill calibration cup with second turbidity standard. Allow solution to settle out until any air bubbles have dissipated.
5. Note turbidity reading and compare to expected value. If turbidity reading is within 1 NTU of the expected value, record readings at both turbidity values. Calibration procedure is complete at this point. If turbidity reading is not within 1 NTU of expected value, proceed to step 6.
6. Go to instrument calibration menu. Starting with the first turbidity standard, fill calibration cup with the turbidity standard. Allow solution to settle out until any air bubbles have dissipated.
7. Enter in the turbidity standard calibration value.
8. Repeat steps 6 and 7 to calibrate with second turbidity standard.

Storage/Maintenance

<u>Total Dissolved Gas</u>

1. Gently clean dissolved gas membrane; rinse with water and scrub *softly* with a soft bristle tooth brush.
2. Gently wipe off excess water around probe. Replace probe with storage cap. TDG membrane needs to be stored dry.
3. Allow membrane to dry for 1-2 days and store in plastic container. For best results, replace with a clean dissolved gas membrane.

<u>Dissolved Oxygen</u>

1. The LDO sensor has a cap with an optical window. If this window appears damaged or discolored, replace the LDO cap.
2. No further field maintenance is recommended. If LDO readings continue to be anomalous, or if readings respond very slowly, the unit must be sent back to the factory for repair.

pH

1. Clean bulb with alcohol and soft Q-tips. Do not use an abrasive scrubbing agent as you could scratch the bulb.
2. pH probe needs to remain moist. Fill ¼ of storage cup with pH 4 solution.
3. Slow probe response time is most likely due to a dirty or scratched pH probe, or new reference electrode solution may be needed.
4. No further field maintenance is recommended. If pH readings continue to be anomalous, or if readings respond very slowly, the unit must be sent back to the factory for repair.

Turbidity

1. Check to be sure the sweeper rubber and brush are intact and properly engage the window for cleaning. Replace brush parts as necessary.