Quality Assurance Project Plan

Pend Oreille River Total Dissolved Gas Total Maximum Daily Load Technical Study

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303(d) listings addressed in this study:
Pend Oreille River Total Dissolved Gas (Proposed 2002/2004 Listing)

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Approvals

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Abstract

This Quality Assurance (QA) Project Plan describes monitoring for Total Dissolved Gas (TDG) in the Pend Oreille River in Washington State, to be used in development of a TDG Total Maximum Daily Load (TMDL). TDG will be monitored continuously in the Pend Oreille River near Ruby, about halfway between Newport and Box Canyon Dam. TDG will also be measured at regular intervals from April through July as paired readings with other meters operated by dam owners above Newport and at Box Canyon and Boundary Dams, as well as at the Ecology meter. Data quality, analytical, and reporting procedures are also described.

Background/Problem Statement

Ecology is determining the TMDL of Total Dissolved Gas (TDG) in the mainstem Pend Oreille River from the Idaho border to the international boundary with Canada (Figure 1). Water quality data from the Pend Oreille River shows that TDG levels exceed state water quality standards. Therefore, the state of Washington has included the Pend Oreille River on Ecology's draft 2002/2004 303(d) list. Because TDG levels have been observed above the water quality standards criterion of 110% of saturation at multiple locations in the river and because the available information does not show TDG being reduced below the criterion between the monitoring points, the entire Pend Oreille River in Washington State must be considered impaired for TDG.

The Pend Oreille River is part of the Pend Oreille/Clark Fork Watershed (Figure 2). The Clark Fork and its tributaries drain the Rocky Mountains in Western Montana and Northern Idaho. The Clark Fork empties into Lake Pend Oreille, and the Pend Oreille River begins at the outlet of the lake. The river enters Washington near the city of Newport and flows northward towards the international border with Canada. Downstream of Newport, the river passes through the reservation of the Kalispel Tribe of Indians. A short reach of the river flows through Canada to its confluence with the Columbia River just upstream of the international border.

The Pend Oreille River is listed for TDG on the State of Idaho's 1998 303(d) list of impaired waters. Monitoring data also show that TDG in the Pend Oreille River exceeds water quality criteria in British Columbia and may contribute to impairment of the Columbia River south of the Canadian border (Pickett *et al.*, 2004; NWPCC, 2003).

The state of Washington will be issuing this TMDL for waters of the state and submitting it to the U.S. Environmental Protection Agency (EPA) for its approval. EPA will be issuing the TMDL for Tribal waters and will coordinate among Washington, Idaho, Montana, Canada, and the Kalispel Tribe. Washington will develop a TMDL implementation plan jointly with the Kalispel Tribe.

Elevated TDG levels are usually caused by spill events at the hydroelectric projects on the river. Water pouring over the spillway of a dam and plunging into tailrace waters entrains air bubbles. When these are carried to depth in the dam's stilling basin, the higher hydrostatic pressure forces air from the bubbles into solution. The result is water supersaturated with dissolved nitrogen, oxygen, and the other constituents of air. As the bubbles rise in the aerated zone of the tailrace, some of the gas leaves solution. However, as the bubbles dissipate and the water enters the downstream reach, the remaining TDG will remain unless wind- or channel-induced turbulence causes more degassing.

Water that passes the dam through the powerhouse usually has the same TDG as upstream. However, at some dams under certain conditions, TDG can be elevated if air is present in the turbines. It is not clear if this occurs at hydropower turbines on the Pend Oreille River. Analysis of the TDG data from the river shows a strong relationship to spills, so spill is clearly the principal cause of high TDG.

TDG may also be affected by natural phenomena:

- High biological primary productivity can raise TDG by raising dissolved oxygen. This may be occurring in Pend Oreille Lake and River.
- For a constant TDG loading level, the percent saturation of TDG can rise if atmospheric barometric pressure drops or if the water temperature increases. These effects are generally stronger when travel time is slower.
- Natural waterfalls and cascades can either increase or decrease gas levels. In general, plunging waterfalls generate gas while cascades passing over rock surfaces can cause degassing. The Albeni Falls project was built on an existing waterfall, which may have affected TDG in the system prior to hydro development. Other waterfalls and areas of cascades and rapids, such as Metaline Falls, Box Canyon, and Z Canyon, are now submerged under reservoirs.

Fish in water with high TDG levels may not display signs of difficulty if higher water pressures at depth offset high TDG pressure passing through the gills into the blood stream. However, if the fish inhabit supersaturated water for extended periods, or rise in the water column to a lower water pressure at shallower depths, TDG may come out of solution within the fish, thus forming bubbles in their body tissues. This gives rise to the condition called "gas bubble trauma" or "gas bubble disease."

Spills can occur at any time when flow exceeds powerhouse capacity ("involuntary" spills). There are three main reasons for involuntary spills:

- The powerhouse cannot pass flood flows.
- The powerhouse is off-line due to lack of power demand.
- The powerhouse is off-line for maintenance or repair.

Spills generally occur during periods of peak flow during spring runoff. Figure 3 shows the tenth percentile, median, and ninetieth percentile daily flow in the Pend Oreille River over twenty-two years of record. Typically the peak flow season occurs during April through July, which is when spill can be expected. Base flows are typically between 10,000 and 30,000 cubic feet per second (cfs), while peak flows can exceed 90,000 cfs. This makes the Pend Oreille one of the largest rivers in Washington in terms of flow, smaller than the Columbia and Snake Rivers but comparable to the Skagit River.

There are a variety of solutions used to abate TDG generation from spill at an existing dam. A few of the most commonly used are:

- Optimize spill gate operation to minimize TDG generation.
- System-wide river flow regulation to minimize spill at downstream dams.
- Increase powerhouse capacity to decrease involuntary spill.
- Install spill deflectors on spillway faces to redirect spill flow horizontally and reduce plunging flow.
- Construct low-level spillways or retrofit spill gates for bottom discharge to reduce spill height and plunging flow.

There are two hydroelectric projects in the TMDL area (Figure 1): Box Canyon Dam (Pend Oreille Public Utility District) and Boundary Dam (Seattle City Light). Just upstream of the TMDL area in Idaho is Albeni Falls Dam (Army Corps of Engineers – Seattle District), which regulates Lake Pend Oreille water levels and controls downstream flows. Other major dams in the Clark Fork upstream of Lake Pend Oreille include Noxon and Cabinet Gorge Dams (Avista), and Hungry Horse Dam (U.S. Bureau of Reclamation).

Box Canyon Dam is a run-of-the-river dam with very little active storage capacity. Reservoir water levels are managed to maximum heights at Cusick and Newport. Spill occurs when that elevation is reached or when the powerhouse has reached hydraulic capacity. As spills generate TDG, downstream TDG levels begin to increase above upstream levels, typically at flows of 30,000 cfs or higher (Figure 4). At very high flows, TDG generation drops off because spill gates are pulled (reducing spill elevation) while tailwater elevations increase, reducing the head difference through the dam and, therefore, decreasing the plunging of the spill.

Boundary Dam is operated for peak load-following and providing operating reserves, meaning water is most often released during the day and the reservoir refills at night. Therefore, reservoir levels experience fluctuations. Spill occurs when powerhouse capacity is at a maximum and reservoir storage is no longer available. Spill begins to increase downstream TDG above upstream levels at around 65,000 cfs (Figure 5). TDG levels can increase at low flows, due to air entering the turbines while they are ramping up or down during generation start-up or shut-down. (Flows are measured downstream and, therefore, are regulated by power operations at Boundary Dam).

Box Canyon and Boundary Dams are each covered by a Federal Energy Regulatory Commission license. Pend Oreille PUD has applied for renewal of the Box Canyon Dam license, received a Section 401 certification from Ecology in 2003, and is expected to receive its new license this year. Boundary Dam's license expires in 2011; therefore, Seattle City Light is just beginning the relicensing process.

The proposed TMDL will need to address the cumulative effects of hydroelectric projects and natural phenomena. To determine loading capacity, pollutant allocations, and evaluate implementation for the TMDL, a combination of monitoring and modeling will be necessary.

TDG has been monitored by Pend Oreille PUD at Newport, Box Canyon Dam forebay, and Box Canyon Dam tailrace since 2001 (Pend Oreille PUD, 2001; 2002; 2003). Monitoring is planned above and below Box Canyon Dam in 2004. The U.S. Geological Survey (USGS) has monitored TDG in the Boundary Dam forebay and tailrace since 2000 (Kimbrough *et al.,* 2000; 2001; 2002). Monitoring will continue in 2004. Monitoring is planned in 2004 by the Army Corps of Engineers at the USGS flow gage just upstream of the Idaho state line near Newport and in the forebay of Albeni Falls Dam. These monitoring locations are shown in Figure 1 ("Project TDG Stations"). Ecology is planning to complement this monitoring with additional monitoring to fill potential data gaps and assess comparability of data, as described below.

Ecology has issued TDG TMDLs for the Lower Columbia River (Pickett and Harding, 2002) and Snake River (Pickett and Herold, 2003), and a draft TDG TMDL has been developed for the Mid

Columbia River and Lake Roosevelt (Pickett *et al.,* 2004). A TDG TMDL is also under development for the Spokane River in Washington. The approaches used in these TMDLs will likely be applied to developing a TDG TMDL for the Pend Oreille River.

Project Description

The overall goal of the project is to set TMDLs by evaluating the effects of dam spills on TDG in the river. Due to extensive monitoring of TDG by Pend Oreille PUD, USGS, and the Army Corps of Engineers, the TMDLs will be developed almost entirely from historic and current data and analysis. More monitoring is planned during the 2004 spring runoff season at the Idaho state line above and below Box Canyon Dam and above and below Boundary Dam (Figure 1). Detailed monitoring studies of TDG downstream of the Albeni Falls Dam spillway may also be conducted.

With respect to the development of the TMDL, there are two main questions that additional data collection can help answer:

- The Box Canyon Reservoir is about 55 miles long and TDG has been monitored at its upper (near Newport) and lower end. Data from these locations show a wide range of change from one end of the reservoir to the other, with a tendency towards increases in TDG (Figure 6). If differences were soley due to time of travel, equal amounts of data should lie above and below the 1:1 line. Degassing, or temperature decreases, would tend to bias data towards lower levels in the forebay. On the other hand, DO increases from productivity or water temperature increases would bias data towards higher levels in the forebay. The pattern of data suggest temperature and productivity may contribute to TDG changes between the head of the reservoir and the dam forebay.

  The upper half of the reservoir is relatively flat and lies in a wide valley. From just upstream of the mouth of LeClerc Creek (and the old town site of Ruby), the valley is relatively narrow and the old river channel dropped more steeply. Continuous monitoring of TDG near Ruby would help to characterize TDG transport and exchange in the reservoir and any differences in TDG exchange processes between the upper and lower halves.

- Monitoring in the river is being conducted by three different entities with different equipment. Replicate measurements would help to evaluate data comparability among these different monitoring locations. Ecology plans to take spot measurements at each continuous monitoring location from upstream to downstream during a single day, to be repeated every two weeks during the spring runoff season.

Previous TMDLs have relied on spreadsheet-based analysis of barometric pressure, wind, and water temperature data to develop allocations, and this may prove true for the Pend Oreille River as well. However, a more complex modeling analysis may need to be considered if the TDG dynamics cannot be evaluated with simpler tools. Examples might include: if the effects of each dam cannot be isolated; if the interation of travel time, productivity, and temperature changes in the reservoirs are signficant; or if an evaluation of system wide effects is needed.

If modeling appears to be needed, existing models (RMB10 and CE-QUAL-W2) will be evaluated for their applicability to this TMDL. Full-scale data collection for a model is not planned, so model development will depend on finding sufficient input data from existing sources. Also, if modification of a model to address TDG is required, the effort may be more resource-intensive than the scope of this study allows. Available data and resources will be evaluated against model development needs; and, if these needs are feasible and reasonable, this model will be used for TMDL development.

Responsibilities

- *Paul Pickett*. Project manager and principal investigator, responsible for overall project management, preparation of the QA Project Plan; supervision and completion of field sampling; analysis of the project data and modeling; and overall preparation of the technical content of the draft and final reports.

- *Jim Ross*. Environmental Assesment Program, Eastern Region. Responsible for the calibration, deployment, maintenance, and retrieval of monitoring equipment as well as for technical assistance with regard to field logistics.

- *Will Kendra, Karol Erickson, and George Onwumere.* Manager/supervisors of the Watershed Ecology Section, Water Quality Studies Unit, and Freshwater Monitoring Unit, respectively, of the Environmental Assessment Program. Responsible for review and approval of the QA Project Plan and draft final report.

- *Stew Lombard*. Responsible for technical assistance on Quality Assurance, including review and approval of the QA Project Plan.

- *Jim Bellatty, David Knight, Jean Parodi, and Paul Turner.* Section manager, watershed unit supervisor, hydropower water quality specialist, and project TMDL coordinator, respectively, for the Eastern Region Section of Ecology's Water Quality Program. Responsible for review and approval of the draft QA Project Plan and draft final report.

- *John Gross and Michele Wingert*. Environmental staff for Kalispel Tribe. Responsible for review of the draft QA Project Plan and final report, focusing on issues pertaining to Kalispel Tribal waters and fisheries.

- *Helen Rueda*. U.S. Environmental Protection Agency, Portland Oregon. Responsible for review of the draft QA Project Plan and final report, focusing on issues pertaining to Kalispel Tribal waters, interstate waters, and international waters.

Schedule

TDG monitoring will be targeting the spring and early summer season, since this is the period of maximum flows from spring runoff. TDG and flow data from USGS and Pend Oreille PUD were analyzed to determine the target season for high TDG levels (Figures 3 through 5). River and snowpack conditions this year look close to average; therefore, the runoff will likely occur from mid-April through mid-July. Therefore, the start of monitoring is targeted for April 20. Monitoring will end in mid-July, or earlier, if an analysis of basin hydrology indicates that the spring season runoff is complete and spill has ended for the season.

Monitoring data will be reported in a data summary along with a detailed report on the results of the data quality assessment. The data summary will be developed in accordance with Program report review guidelines, distributed as a draft first to the project lead entities (Ecology client, Kalispel Tribe, and EPA staff) and then revised and distributed as a draft to stakeholders and interested public. Final publication of the data summary will be as an appendix to the TMDL submittal document. Digital archiving of data in the EIM database will be in accordance with EA Program guidelines. Monitoring data, modeling results, and the results of other analyses will be presented in the TMDL submittal reports. The schedule for the data and TMDL submittal reports is shown in Table 1.

Table 1. Project Milestones

Report	Milestone	Due Date
Data Technical Appendix		
	Draft Internal Review	December 2004
	Draft External Review	January 2005
TMDL Submittal Report		
	Draft Internal Review	May 2005
	Draft External Stakeholder Review	June 2005
	Final Draft to Formal Public Comment	September 2005
	Report Submitted to EPA	December 2005
	EIM Data Entry Completed	July 2005

Data Quality Objectives and Decision Criteria

TDG meters, like other field monitoring equipment, are subject to bias due to systematic errors introduced by calibration, equipment hardware or software functioning, or field methods. Bias will be minimized by following standard protocols for calibration and maintenance, and by following field protocols for stabilization of meter readings. Bias is difficult to assess for TDG field measurements, because a more accurate verification method, such as a laboratory standard, is not available. No Data Quality Objectives (DQOs) are being set for bias.

The precision of the results from continuous monitoring instruments cannot be estimated from replicate measurements. In this study, the potential variability of TDG results may be indicated by agreement among the simultaneous results from two or more instruments, either during calibration or in the field.

Most TDG measurements are expected to fall into the range of 100% to 140% saturation. State criteria are currently set at 110% saturation. Measurement Quality Objectives (MQOs) are equivelant to DQOs for this study, equal to 1% saturation. This is similar to MQOs reported by the USGS for the fixed monitoring system in the lower Columbia (Tanner and Bragg, 2001). MQOs will be met if TDG meter readings are within 1 percent saturation or 5 mm Hg of the expected value based on comparison to calibration values (pressurized chamber) or duplicate measurements (paired readings of Ecology meters). Paired readings will be evaluated by the residuals of pairs and the root mean square error of all pairs for the season.

MQOs will also be evaluated for any paired readings of Ecology meters with other field meters (Army Corps, Pend Oreille PUD, or USGS). If MQOs are not met for these pairs, the differences between paired data will be evaluated, including differences in the data quality procedures used, but the data will not be qualified or discarded unless other information indicates problems with the data. The variability between Ecology and other meters will be taken into account during TMDL development, which could be by error analysis or by standardizion of data bias.

TDG percent saturation measurements are dependent upon barometric pressure (BP) readings, so secondary MQOs are also needed for the on-site BP measurement method used. The target for this study will be an MQO of 2 mm Hg for the field barometer readings or BP estimation method. The BP MQO will be evaluated by paired readings with a field barometer, Hydrolab pressure sensor with the TDG membrane removed, BP readings from other barometers used for TDG measurement (Army Corps, Pend Oreille PUD, or USGS), or barometers at Deer Park Airport and Kalispel Tribal headquarters. If BP MQOs are exceeded, the data will still be acceptable if the TDG percent saturation MQOs are met.

Water quality data will also be collected for temperature, dissolved oxygen, pH, and conductivity. Since these are parameters of secondary importance to the study, DQOs have not been established but MQOs will be set to determine if data are acceptable for reporting (Table 2). The MQO for water quality data will be met and reported if post-calibration shows that the temperature is within 0.5 ^{o}C, if pH is within 0.5 standard units, if DO is within 0.5 mg/L, and if

conductivity is within 5% or 5 microSiemens/centimeter (μS/cm). MQOs will be assessed using standards or paired readings.

Table 2. Study MQOs

Parameter	Measurement Quality Objective
Total Dissolved Gas Saturation	1% or 5 mm Hg
Temperature	0.5 ^{o}C
pH	0.5 standard units
Dissolved Oxygen	0.5 mg/L
Conductivity	5% or 5 μS/cm
Barometric Pressure (Field)	1 mm Hg

DQOs are not being specified for existing data or for modeling results. However, the following acceptance criteria will be applied:

- **Data Reasonableness:** Data quality of existing data will be evaluated where available. Sources within well-established programs will be acceptable based on the credibility of the source (such as National Weather Service or the USGS data). Data will be reviewed for whether the amount of variability is appropriate, based on statistical measures, expected values, and comparison between data sets. Data with too much or too little variability will not be used.

- **Data Completeness:** Data sets will be used that are reasonably complete during the period of interest. Incomplete data sets will be used if they are considered representative of conditions during the period of interest.

- **Data Representativeness:** Data will be used that are representative of the location or time period under consideration. For example, attention will be paid to the variations in meteorological conditions throughout the TMDL study area, and to seasonal differences between high and low flow conditions.

- **Model Calibration and Verification:** The primary measure of calibration and verification success will be by comparing observed versus modeled TDG percent saturation. Bias will be measured by the average residual of paired values (observed-modeled) and precision by the root mean square error of paired values. The goal of this study will be a bias of less than 0.1% saturation and precision of less than 1% saturation. A greater precision and bias will be acceptable if the model successfully predicts the average days per year that the river exceeds the water quality criterion and visual inspection of the time series shows good matching of the patterns of TDG.

Study Design and Field Procedures

Ecology currently has three Hydrolab® Datasonde® 4 meters with TDG sensors. These meters can be deployed for extended periods while measuring and storing data internally. Similar meters are measuring TDG throughout the Columbia and Snake River Basins with good success. Generally, they are deployed for two-week to one-month periods between download and recalibration.

For monitoring in the Pend Oreille River, one deployment site will be identified that is optimal for monitoring both logistically and for representativeness. The approximate location of the site will be downstream of the town of Jared (about River Mile 60) near Ruby (River Mile 56) or as far downstream as Blueslide (River Mile 52), depending on the ability to find a suitable location.

A location will be determined that ideally would meet the following criteria:

- The meter can be deployed at a depth of five meters or more during all expected flows to ensure that data is collected below the compensation depth.
- The tube is protected from floating river debris with a PVC housing and a protected deployment location.
- The tube is easily accessed without a boat; for example, from a dock.
- The site can be secured from vandalism.
- The site will be located either in the river current or away from milfoil beds.

Field staff will mount, monitor, and maintain the tube. A meter will be deployed in the tube and at two week intervals the deployed meter will be replaced with another calibrated meter and returned to the lab, where data will be downloaded and the meter recalibrated and prepared for redeployment. During meter replacement, side-by-side readings will be taken with the meter to be replaced, the replacement meter, and the synoptic survey meter.

Since the TMDL will be based on TDG data from multiple sources, Ecology will conduct synoptic surveys to obtain replicate readings from the continuous TDG monitoring locations. This will provide a baseline of monitoring information to validate the comparability of data.

Once about every two weeks during the monitoring period (the spill season), synoptic surveys will be conducted of the Pend Oreille River at each meter collecting continous TDG data from below Albeni Falls Dam to below Boundary Dam where access by vehicle is possible (bridges, docks, and dams). Each survey will begin at the upstream end and proceed down the river over the course of one day. Monitoring locations will be side-by-side with the continuous meter or from other access as close to the continuous meter as possible. (Monitoring sites are the TDG stations shown in Figure 1.)

Because TDG percent of saturation is calculated as TDG pressure divided by ambient barometric pressure, BP data quality is critical. BP can either be determined by direct measurement with a datalogging barometer or by calculation from neighboring meteorological data sites. The latter method is preferred due to cost. Local barometric pressure data should be available at the TDG

monitoring stations (Albeni Falls Dam, Box Canyon Dam, and Boundary Dam) and at the Kalispel Tribe office in Usk. Other weather stations with BP data are available in the region including Spokane Airport, Deer Park Airport, Sandpoint Idaho, and Colville Airport. A handheld digital barometer will be used to measure BP at each monitoring station, at the Kalispel Tribe office, and at the Deer Park Airport. BP values for the Ecology monitoring station will be calculated from neighboring BP stations. Calculated and other measured values will be checked with the readings from the barometer and the Hydrolab pressure sensor without the TDG membrane. If bias is detected from any stations, then correction methods will be evaluated to maximize consistency between data. Regional weather stations will be used for qualitative BP data evaluation.

Data acquisition from a variety of existing sources will be necessary for the TMDL analysis. TDG data from non-Ecology monitoring sites and spill release volumes at the dams will be obtained after the surveys from appropriate staff. Meterological and flow data are generally available from the source agencies on the Internet.

Data will be analyzed to evaluate a number of relevant parameters in the TMDL study area during the TMDL season:

- Critical low barometric pressures.
- Wind and its effect on gas exchange.
- Water temperature increases and their effect on TDG levels.
- River flow and dam spill discharge and configuration.
- TDG generation by each project.

Data for these analyses will be available from either Ecology, National Weather Service, USGS, dam operators, Kalispel Tribe, or other local entities.

TMDL development will follow standard TMDL protocols and will follow an approach similar to the Columbia and Snake River TDG TMDLs.

Laboratory Procedures

No laboratory work is planned.

Quality Control Procedures

Field Quality Control

Meters will be calibrated for TDG before every deployment and post-calibrated after each deployment in Ecology's Eastern Regional Office laboratory. A lab sheet has been developed for TDG calibration and post-calibration of the meters (Appendix A). TDG calibration and post-

calibration procedures will follow Standard Method SM 2810B (APHA *et al.*, 1995), manufacturer's instructions, and USGS protocols for TDG (Tanner and Johnston, 2001).

Water quality parameters other than TDG will be calibrated before each deployment if pre- or post-calibration show MQOs are not being met. Pre- and post-calibration for temperature, pH, and conductivity will consist either of paired meter readings in a water bath or comparison to a standard. Pre- and post-calibration for DO will consist either of paired meter readings in an air-saturated water bath or air calibration. Calibration for pH, conductivity, and DO (temperature is factory calibrated) will follow manufacturer's instructions and Ecology's standard protocols (Ecology, 1993).

Meters will be checked for proper performance at the deployment site at the beginning and end of each deployment. A field data sheet has been developed to check performance in the field (Appendix B). Paired readings between Ecology meters will be evaluated in the field for comparability and comparison to MQOs. Paired readings between Ecology meters and other datalogging meters (the three dam sites) will be evaluated post-survey as the data becomes available.

Data Review, Quality Assessment, and Validation

Data Review and Validation

Data will be downloaded from the meters to a spreadsheet and reviewed for outliers and values exceeding MQOs. Outliers and data that exceed the MQOs will be evaluated for the cause of the problem. Slight exceedences will be tolerated, with the data qualified and the poorer precision taken into account in data analysis. Exceedences that can be traced to membrane, or other equipment failure, will result in rejection of the data.

Data completeness will be adequate if monitoring is completed with data meeting the MQOs at least 85% of the time (equivalent to about one day per week of lost data). A lower rate of data completeness will be acceptable; all data meeting MQOs will be used.

The results of modeling and other analyses will be evaluated for compliance with acceptance criteria. Any shortcomings in the analyses will be taken into account in the development of a margin of safety for the TMDL. Every effort will be made to complete the TMDL with data collected by this study and existing data. However, if the quality of data or analytical results is sufficiently poor and the margin of safety unreasonably high, completion of the TMDL may be postponed while addional data is collected and analyses conducted.

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Figures

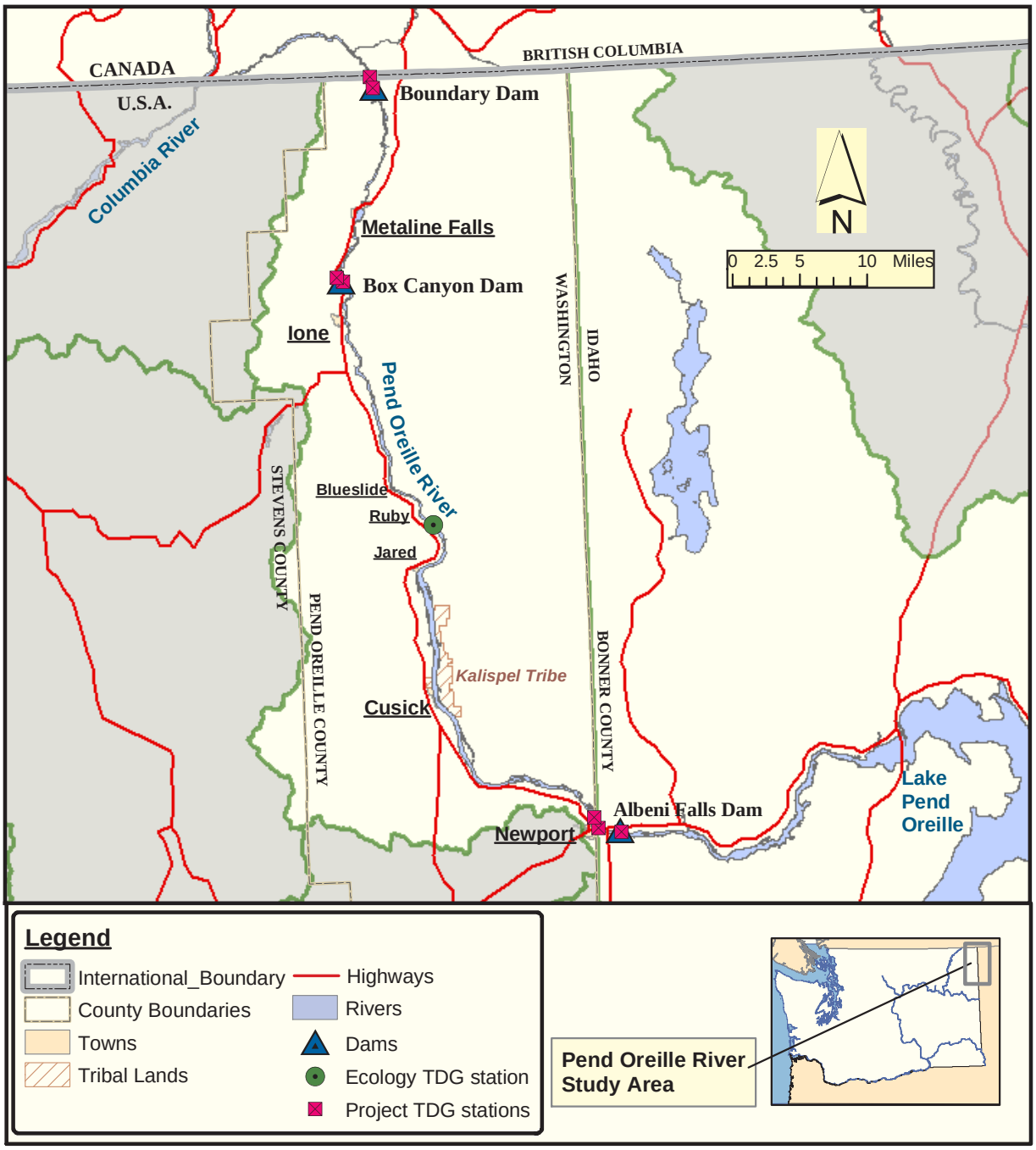

Figure 1. Pend Oreille River TDG TMDL Study Area (Washington), as well as upstream (Idaho) and downstream (British Columbia) neighboring areas

Figure 2. Pend Oreille/Clark Fork Watersheds (within the United States)

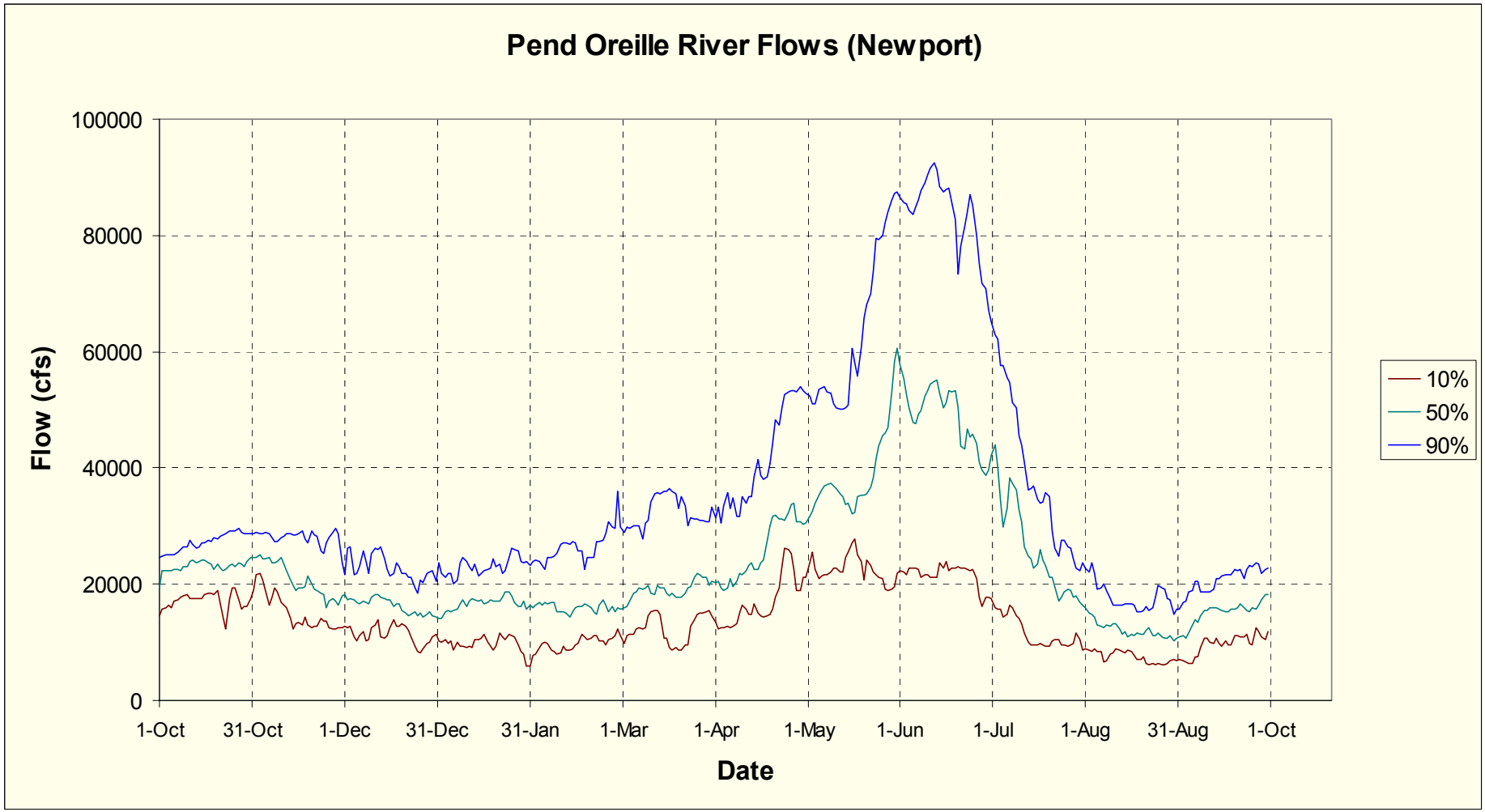

Figure 3. Pend Oreille River daily 10th percentile, median, and 90th percentile flows at Newport (1981- 2002)

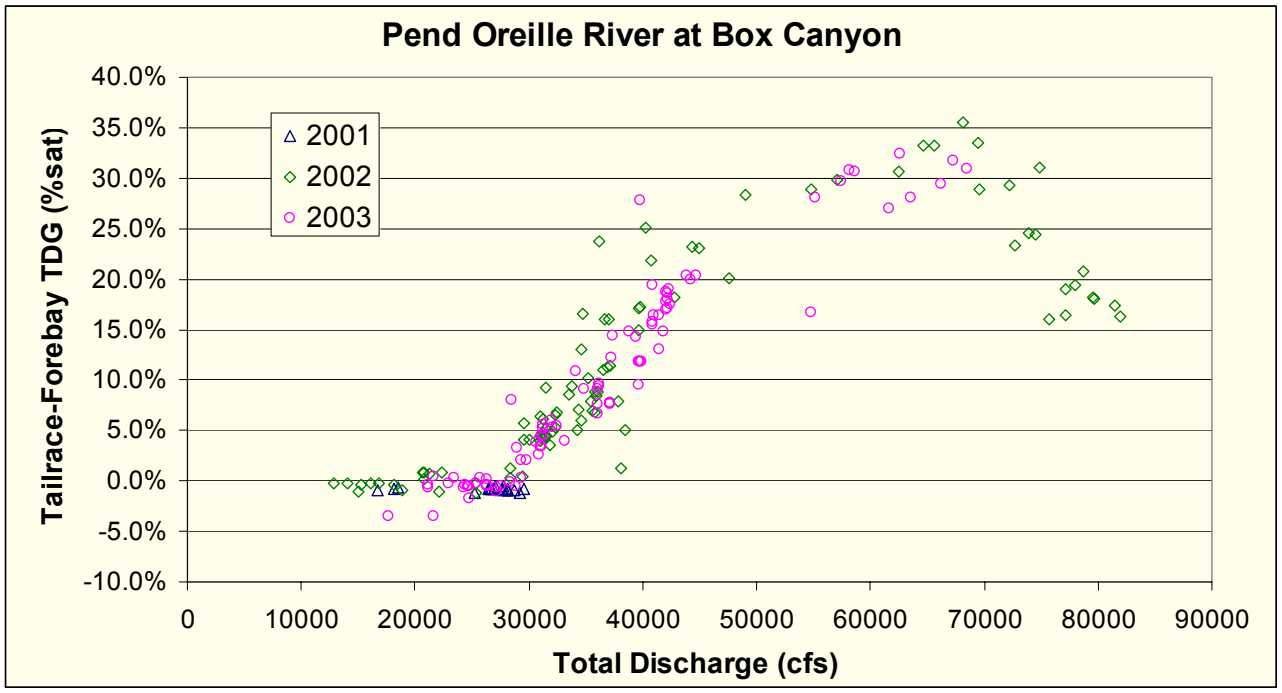

Figure 4. Flows versus TDG change at Box Canyon Dam (2001- 2003 spill season)

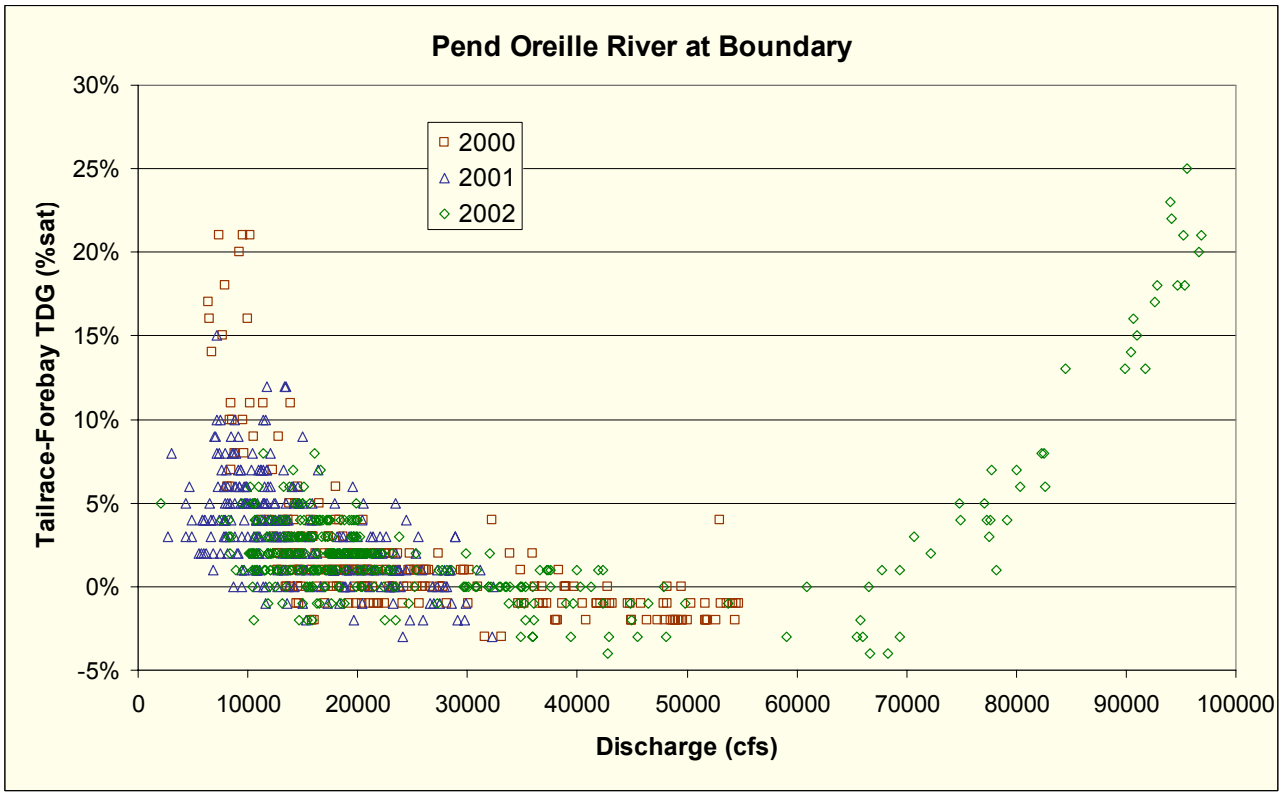

Figure 5. Flows versus TDG change at Boundary Dam (2000- 2002 spill season)

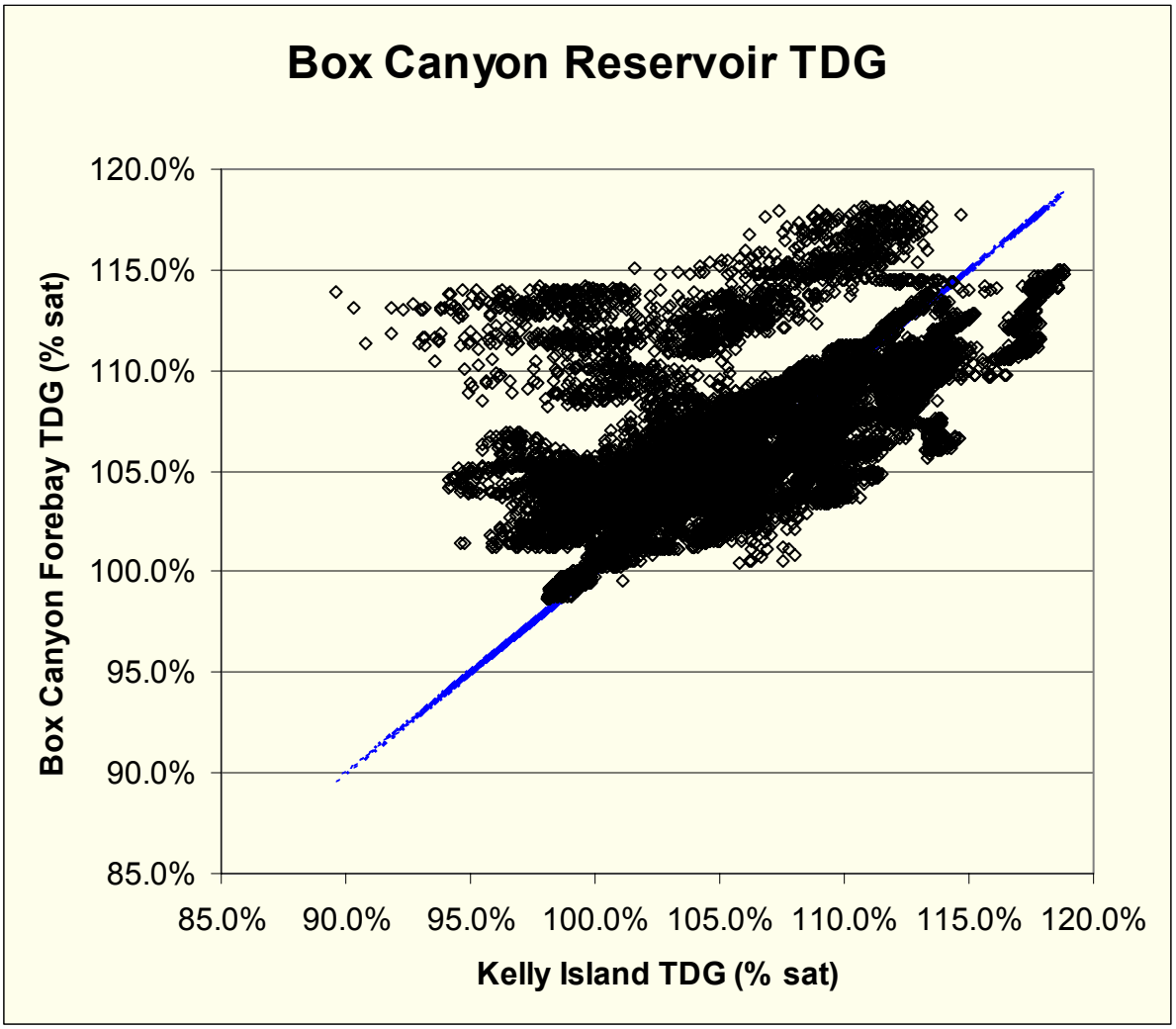

Figure 6. Kelly Island (Newport) vs Box Canyon Dam Forebay TDG (2000- 2002 spill season)

Appendix A

Calibration Data Sheets

HYDROLAB CALIBRATION PROCEDURES (To be done prior to survey)

Hyrolab #_____ Lab barometer ID _____
TDG sensor #_____ Date barometer last calib. _____
Survey location _____ Today's date _____
Survey Date _____ Checked by _____

1. CALIBRATE TDG WITH DIGITAL PRESSURE GAUGE (MEMBRANE OFF).

Lab BP _____ mm Hydrolab ambient pressure _____ mm Time _____
Baro+100mm: expected/measured _____ /_____
Baro+200mm: expected/ measured _____ /_____
Baro+300mm: expected/ measured _____ /_____

If any readings are >2 mm off, do a 2-point calibration at BP and BP+200 mm and note below.
Calibration BP: calibrated/measured _____ /_____
BP+200mm: calibrated/ measured _____ /_____

2. INSTALL DRY MEMBRANE AND TEST HYDROLAB WITH PRESSURE GAGE AND CHAMBER.

Lab BP + 200mm = _____ mm
Before applying 200 mm pressure Hydrolab pressure _____ mm Time _____
After applying pressure Hydrolab pressure _____ mm Time _____

3. INSTALL SENSOR GUARD AND TEST HYDROLAB WITH CLUB SODA.

Before soda test Hydrolab pressure _____ mm * Time _____
High pressure, soda test Hydrolab pressure _____ mm Time _____
Low pressure, after soda test Hydrolab pressure _____ mm Time _____

4. CHECK MEMBRANE FOR INTERNAL MOISTURE AFTER THE OUTSIDE HAS HAD TIME TO DRY.

HYDROLAB TDG POST-CALIBRATION PROCEDURES (To be done at the conclusion of a survey.)

Today's date _____ Checked by _____

1. TEST LOW CALIBRATION WITH MEMBRANE ATTACHED.

Lab BP _____ mm Hydrolab Pressure _____ mm Time _____

2. TEST HYDROLAB WITH DIGITAL PRESSURE GAGE AND PRESSURE CHAMBER.

Lab BP + 200mm = _____ mm
Before applying 200 mm pressure Hydrolab pressure _____ mm Time _____
After applying pressure Hydrolab pressure _____ mm Time _____

3. TEST HYDROLAB WITH CLUB SODA.

Before soda test Hydrolab pressure _____ mm Time _____
High pressure, soda test Hydrolab pressure _____ mm Time _____
Low pressure, after soda test Hydrolab pressure _____ mm Time _____

(If the unit does not perform well on #1-3 above, re-evaluate the corresponding site record.)

Remove TDG membrane, clean the membrane, air dry, store with desiccator.
Allow TDG sensor to air dry for at least 24 hours.

HYDROLAB TDG FIELD INSPECTION/CALIBRATION SHEET

Deployment/Retrieval Procedures

Project: _____ Date: _____ Personnel: _____

Weather: _____ Air temperature: _____ ^{o}C

Observed river conditions (flow, spill, etc.): _____

Barometer ID _____ Date last cal._____ Survey meter #:_____

1. Take reading at Oldtown Bridge (Albeni Falls tailwater). Start time:_____; Site conditions:_____

BP:_____; Depth:_____; TDG:_____; DO:____; pH:_____; Cond:_____; Temp:_____;

2. Take readings with both meters at Ecology monitoring site. Site conditions:_____

Start time:_____ Bar Press:_____

Meter #:___; Time:___; Depth:_____; TDG:_____; DO:____; pH:_____; Cond:_____; Temp:_____;

Meter #:___; Time:___; Depth:_____; TDG:_____; DO:____; pH:_____; Cond:_____; Temp:_____;

After a minimum of 15 minutes, if both Hydrolab readings have not changed 1 mm./2 min, or if meters are changing but difference is constant:

_____ mm (DS#____) - _____ mm (DS#____) = _____ mm Time: _____

IF Difference is > 10 mm, do A and B

A. Test both Datasondes with club soda:

DS#____ ; TDG:_____ mm Time: _____

DS#____; TDG:_____ mm Time: _____

B. Test both Datasondes with pressure gage and chamber:

DS#____: ambient_____ mm; plus 200mm_____ mm Time: _____

DS#____: ambient_____ mm; plus 200mm_____ mm Time: _____

IF DATASONDE FAILS EITHER TEST, REPLACE MEMBRANE AND RETEST, OR DO NOT USE.

Old meter retrieval time:_____, new meter deployment time:_____. End time:_____ BP:_____

3. Take reading at Box Canyon forebay. Start time:_____; Site conditions:_____

BP:_____; Depth:_____; TDG:_____; DO:____; pH:_____; Cond:_____; Temp:_____

4. Take reading at Boundary forebay. Start time:_____; Site conditions:_____

BP:_____; Depth:_____; TDG:_____; DO:____; pH:_____; Cond:_____; Temp:_____

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