U.S. Department of the Interior
U.S. Geological Survey

Data-Collection Methods, Quality-Assurance Data, and Site Considerations for Total Dissolved Gas Monitoring, Lower Columbia River, Oregon and Washington, 2000

Water-Resources Investigations Report 01–4005

Prepared in cooperation with the
U.S. ARMY CORPS OF ENGINEERS

USGS
science for a changing world

Cover Photograph. Columbia River at John Day Dam, April 2000. (*Photograph by Amy Brooks, U.S. Geological Survey)*

U.S. Department of the Interior
U.S. Geological Survey

Data-Collection Methods, Quality-Assurance Data, and Site Considerations for Total Dissolved Gas Monitoring, Lower Columbia River, Oregon and Washington, 2000

By DWIGHT Q. TANNER AND MATTHEW W. JOHNSTON

Water-Resources Investigations Report 01–4005

Prepared in cooperation with the
U.S. ARMY CORPS OF ENGINEERS

Portland, Oregon: 2001

U.S. DEPARTMENT OF THE INTERIOR
BRUCE BABBITT, Secretary

U.S. GEOLOGICAL SURVEY
Charles G. Groat, Director

For additional information contact:

District Chief
U.S. Geological Survey
10615 S.E. Cherry Blossom Drive
Portland, OR 97216-3159
E-mail: info-or@usgs.gov
Internet: http://oregon.usgs.gov

Copies of this report can be purchased from:

USGS Information Services
Box 25286, Federal Center
Denver, CO 80225-0046
Telephone: 1-888-ASK-USGS

Suggested citation:

Tanner, D.Q., and Johnston, M.W., 2001, Data-collection methods, quality-assurance data, and site considerations for total dissolved gas monitoring, lower Columbia River, Oregon and Washington, 2000: U.S. Geological Survey Water-Resources Investigations Report 01–4005, 19 p.

CONTENTS

FIGURES

TABLES

Data-Collection Methods, Quality-Assurance Data, and Site Considerations for Total Dissolved Gas Monitoring, Lower Columbia River, Oregon and Washington, 2000

By Dwight Q. Tanner and Matthew W. Johnston

ABSTRACT

Excessive total dissolved gas pressure can cause gas-bubble trauma in fish downstream from dams on the Columbia River. In cooperation with the U.S. Army Corps of Engineers, the U.S. Geological Survey collected data on total dissolved gas pressure, barometric pressure, water temperature, and probe depth at eight stations on the lower Columbia River from the John Day forebay (river mile 215.6) to Camas (river mile 121.7) in water year 2000 (October 1, 1999, to September 30, 2000). These data are in the databases of the U.S. Geological Survey and the U.S. Army Corps of Engineers. Methods of data collection, review, and processing, and quality-assurance data are presented in this report.

INTRODUCTION

The U.S. Army Corps of Engineers (USACE) operates several dams in the Columbia River Basin, which encompasses 259,000 square miles of the Pacific Northwest. These dams are multipurpose facilities that fill regional needs for flood control, navigation, irrigation, recreation, hydropower production, fish and wildlife habitat, water-quality maintenance, and municipal and industrial water supply. When water is released over the spillways of these dams, air is entrained in the water, sometimes increasing the concentration of total dissolved gas (TDG) downstream from the spillways in excess of the U.S. Environmental Protection Agency's water-quality criterion of 110-percent saturation for the protection of freshwater aquatic life. Concentrations above this criterion have been shown to cause gas-bubble trauma in fish and adversely affect other aquatic organisms (U.S. Environmental Protection Agency, 1986). USACE minimizes spill and regulated streamflow in the region to minimize the production of excess TDG downstream from its dams. USACE collects real-time TDG data (data available within about 4 hours of current time) upstream and downstream from the dams in a network of fixed-station monitors.

Background

Real-time TDG data are vital to USACE for dam operation and for monitoring compliance with environmental regulations. The data are used by water managers to maintain water-quality conditions that facilitate fish passage and survival in the lower Columbia River. The U.S. Geological Survey (USGS), in cooperation with the Portland District of USACE, has collected TDG and related data in the lower Columbia River every year beginning in 1996. A report was published in 1996 that contained a description of the methods of data collection, the quality-assurance program, and summaries of data (Tanner and others, 1996).

Data-collection methods and quality-assurance plans have changed significantly since 1996. In water year 2000, new TDG/temperature probes and new methods of calibration in the laboratory and in the field were used.

To provide a suitable data set for water managers to model TDG in the lower Columbia River, the real-time hourly data for water year 2000 were corrected or deleted to reflect measurements made during instrument calibration. The reviewed and corrected hourly data are stored in a USGS data base (Automated Data Processing System—ADAPS) and in a USACE data base at http://www.nwd-wc.usace.army.mil/TMT/tdg_data.

Purpose and Scope

The purpose of TDG monitoring is to provide USACE with (1) real-time data for managing streamflows and TDG levels upstream and downstream from its project dams in the lower Columbia River and (2) reviewed and corrected TDG data to evaluate conditions in relation to water-quality criteria and to develop a TDG data base for modeling the effect of various management scenarios of streamflow and spill on TDG levels.

This report describes the data-collection techniques and quality-assurance data for the TDG monitoring program on the Columbia River from the forebay of the John Day dam (river mile [RM] 215.6) to Camas (RM 121.7). Data for water year 2000 included total dissolved gas pressure, barometric pressure, and water-temperature at eight fixed stations on the lower Columbia River (fig. 1, table 1).

Acknowledgments

We wish to acknowledge the aid and funding support of the U.S. Army Corps of Engineers. Our special thanks to James L. Britton (USACE) for technical and logistical support of the project. The authors also acknowledge Amy Brooks and Tirian Mink (USGS) for assistance in data collection and for preparing summaries of data. Howard E. Harrison, formerly of the USGS, helped develop several of the data-collection and quality-assurance protocols.

METHODS OF DATA COLLECTION

Instrumentation

Instrumentation at each fixed station consisted of a TDG probe, an electronic barometer, a data-collection platform (DCP), and a power supply. The TDG probe was manufactured by Hydrolab Corporation. The probe had individual sensors for TDG, temperature, and probe depth (unvented sensor). The TDG sensor consisted of a cylindrical framework wound with a length of Silastic

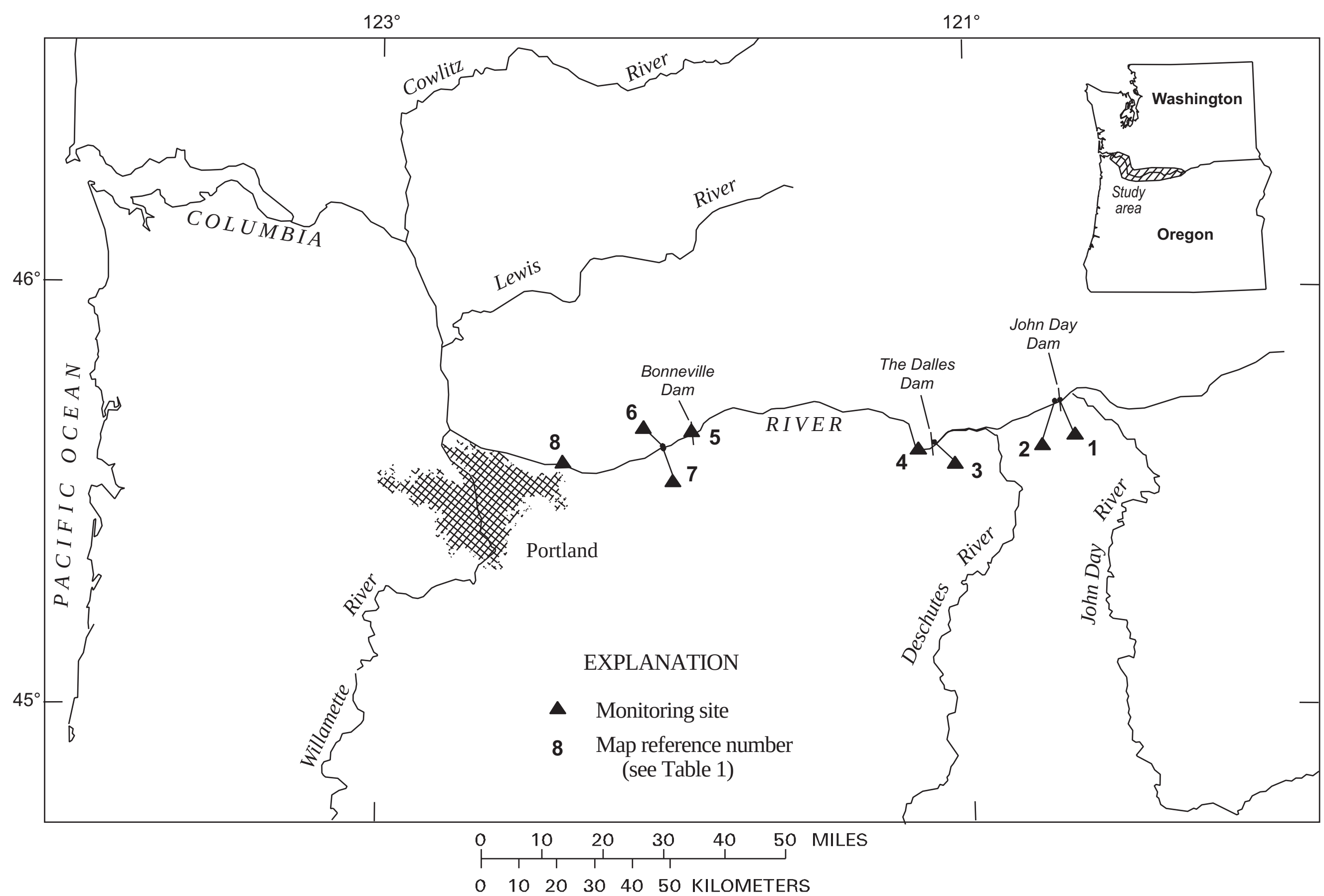

Figure 1. Total dissolved gas fixed stations, lower Columbia River, Oregon and Washington, water year 2000.

Table 1. Total dissolved gas fixed stations, lower Columbia River, Oregon and Washington, water year 2000

[Map reference number refers to figure 1; USACE, U.S. Army Corps of Engineers; Columbia River mile locations were determined from U.S. Geological Survey (USGS) 7.5-minute topographic maps; stations are referenced by their abbreviated name in this report]

Map reference number	USACE site identifier	Columbia River mile	USGS station number	USGS station name (abbreviated station name)	Latitude	Longitude	Period of record
1	JDA	215.6	454257120413000	Columbia River at John Day Dam forebay, Washington (John Day forebay)	45˚ 42’ 57”	120˚ 41’ 30”	March 24 – September 19
2	JHAW	214.7	454249120423500	Columbia River, right bank, near Cliffs, Washington (John Day tailwater)	45˚ 42’ 49”	120˚ 42’ 35”	March 23 – September 19
3	TDA	192.6	453712121071200	Columbia River at The Dalles Dam forebay, Washington (The Dalles forebay)	45˚ 37’ 12”	121˚ 07’ 12”	March 24 – September 20
4	TDDO	188.9	14105700	Columbia River at The Dalles, Oregon (The Dalles downstream)	45˚ 36’ 27”	121˚ 10’ 20”	March 23 – September 19
5	BON	146.1	453845121562000	Columbia River at Bonneville Dam forebay, Washington (Bonneville forebay)	45˚ 38’ 45”	121˚ 56’ 20”	Year-round
6	SKAW	140.5	453651122022200	Columbia River, right bank, near Skamania, Washington (Skamania)	45˚ 36’ 51”	122˚ 02’ 22”	February 23 – September 18
7	WRNO	140.4	453630122021400	Columbia River, left bank, near Dodson, Oregon (Warrendale)	45˚ 36’ 30”	122˚ 02’ 14”	Year-round
8	CWMW	121.7	453439122223900	Columbia River, right bank, at Washougal, Washington (Camas)	45˚ 34’ 39”	122˚ 22’ 39”	February 24 – September 18

(dimethyl silicon) tubing. The tubing was tied off at one end and the other end was connected to a pressure transducer. After the TDG pressure in the river equilibrated with the gas pressure inside the tubing (about 15 to 20 minutes), the pressure transducer produced a measure of the TDG pressure in the river. The water-temperature sensor was a thermocouple. The barometer was contained in the display unit of the Model TBO-L, a total dissolved gas meter manufactured by Common Sensing, Inc.

The TDG probe was connected by a heavy-duty, weatherproof cable to a Sutron Model 8200 DCP. The DCP had three basic functions: sensor interfacing, data storage, and data transmission to the Geostationary Operational Environmental Satellite (GOES) system (Jones and others, 1991). A crossed Yagi antenna was connected to the DCP using a coaxial cable. The antenna was mounted on a mast to provide transmission to the GOES system.

The barometer, TDG probe, and the DCP were powered by a 12-volt gelled-electrolyte battery. The battery was charged by a regulated-voltage circuit from a solar panel and/or a 120-volt alternating-current line.

The DCP was programmed to record and transmit five parameters: barometric pressure (in millimeters of mercury), TDG pressure (in millimeters of mercury), probe depth (in feet), water temperature (in degrees Celsius), and battery voltage (in volts). Battery-voltage data were monitored to determine whether the instrumentation was receiving adequate power. The data for each parameter were logged electronically every hour, on the hour, and stored in the DCP memory. Every 4 hours, the DCP transmitted the most recent 12 hours of logged data to the GOES satellite. Consequently, each piece of data was transmitted three times to protect against data loss. The GOES satellite retransmitted the data to a direct readout ground station, where the data were automatically decoded and transferred to the USACE data base (Columbia River Operation Hydromet Management System—CHROMS), and to the USGS ADAPS data base. During the fixed-station calibration visits, the DCP-stored data were downloaded to a palmtop computer. When it was necessary to fill in any real-time data lost during satellite transmission, these data were supplied to USACE and also loaded into the database at the USGS office in Portland, Oregon.

At one site, John Day tailwater, two TDG probes were installed inside the same probe housing, which was perforated at the end and extended into the flow of the Columbia River. The primary probe was at the distal end of the plastic pipe and the secondary probe was located about 1 foot (measured vertically) above the first. This was done for the following reasons: (1) to ensure that data were reliably collected at this important site and (2) to provide an assessment of the variability of the TDG measurement.

Calibration of Instruments in the Laboratory

The fixed station monitors were calibrated every 2 weeks from March 10 to September 15, 2000, and every 3 weeks for the remainder of the year, at which time Warrendale and Bonneville forebay were the only sites in operation. The general procedure was to check the operation of the TDG probe in the field without disturbing it, replace the field probe with one that had just been calibrated in the laboratory, and then check the operation of the newly deployed field probe. The details of the laboratory calibration procedure follow.

Each time a TDG probe was removed from its 2- or 3-week deployment in the river, it was calibrated in the Oregon District laboratory before being redeployed. First, the TDG value in millimeters of mercury was measured in ambient conditions with the TDG membrane still attached to the sensor and compared to the ambient barometric pressure as measured by a handheld aneroid barometer (fig. 2, item 1). (The aneroid barometer was calibrated every 2 weeks at the National Weather Service facility in Portland, Oregon.) If the measurement by the TDG probe and the measurement by the aneroid barometer were approximately equal, this check was considered acceptable.

Pressure calibrations were done using a Netech DigiMano 2000 digital pressure gage, which was certified according to standards of the National Institute of Standards and Technology (NIST). The end of the TDG probe containing the sensors was put in a plastic pressure chamber and the pressure was increased 200 mm Hg (millimeters of mercury) above the ambient barometric pressure (fig. 2, item 2). The pressure measured by the TDG sensor should increase gradually, until it reaches a level approximately 200 mm Hg above barometric pressure, within about 10 minutes. This would indicate that the pressurized air was penetrating the membrane at a gradual rate. On occasions when there was an opening torn in the membrane, the pressure measured by the TDG sensor would increase rapidly, indicating that the membrane should be replaced.

HYDROLAB LABORATORY PROCEDURES

To be done when a Hydrolab is brought in from a 2 or 3-week deployment.

Hyrolab # 37603 Lab barometer ID dqt
TDG sensor # 63369 Date baro last calib. 5/18/00
Site Hyd. was deployed SKAW Today's date 6/13/00
Date removed 6/5/00 Checked by TM

1. TEST LOW CALIBRATION WITH MEMBRANE ATTACHED.

Lab BP 765 mm Hydrolab Pt 762 mm Time 1403

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

Lab BP + 200mm = 965 mm

Before applying 200 mm pressure Hydrolab Pt 762 mm Time 1403
After applying pressure Hydrolab Pt 964 mm Time 1412

3. TEST HYDROLAB WITH CLUB SODA.

Before soda test Hydrolab Pt 760 mm Time 1519
High pressure, soda test Hydrolab Pt 1011 mm Time 1520
Low pressure, after soda test Hydrolab Pt 728 mm Time 1522

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

Remove TDG membrane, clean the membrane, air dry, store in dessicator.
Allow TDG sensor to air dry for at least 24 hours.
Then test Hydrolab before redeployment, below.

---

1. CALIBRATE TDG WITH DIGITAL PRESSURE GAGUE.

Date 6/14/00
Time 1415

Lab BP 762 mm
Hydrolab Pt 760 mm

862 860
Baro+100mm expected/meas.

962 961
Baro+200mm expected/meas.

1062 1061
Baro+300mm expected/meas.

If any readings are >2 mm off, do a 2-point calibration at barometric pressure and barometric pressure + 200 mm and note below.

2. INSTALL DRY MEMBRANE AND INSTALL THE SENSOR GUARD.

3. TEST HYDROLAB WITH CLUB SODA. 6/15/00 baro=767

Before soda test Hydrolab Pt 771 mm Time 0907
High pressure, soda test Hydrolab Pt 1002 mm Time 0908
Low pressure, after soda test Hydrolab Pt 746 mm Time 0909

4. CLEAN AND DRY THE HYDROLAB.

5. CHECK MEMBRANE FOR INTERNAL MOISTURE AFTER THE OUTSIDE OF THE MEMB. HAS HAD TIME TO DRY

Label as ready for field deployment, with date. Completed Date 6/16/00 Time 1400

Figure 2. Laboratory calibration form.

Subsequently, the TDG membrane / TDG sensor units were tested for responsiveness to supersaturation by inserting the probe into a container filled with supersaturated carbonated water (club soda). If the membrane/sensor was operating correctly, the measured TDG rose to at least 1,000 mm Hg in 2 to 3 minutes (fig. 2, item 3). If the response was not this large, the membrane was replaced.

Next, the TDG membrane was cleaned with a squirt bottle of tap water, then removed from the sensor. The TDG membrane was dried in a desiccator for at least 24 hours, and, at the same time, the TDG sensor was air dried at room temperature. This step was important because water sometimes collected inside the tubular membrane due to condensation. If the condensation is not removed, it can slow the equilibration of air pressure between the outside of the membrane and the TDG sensor.

After the TDG membrane and sensor had been dried, the TDG sensor, with the membrane still unattached, was tested at ambient pressure conditions (i.e. barometric pressure, as measured by the aneroid barometer) and at added pressures of 100 mm Hg, 200 mm Hg, and 300 mm Hg measured by the pressure gage, which was the primary standard (lower half of fig. 2, item 1). For example, using the barometric pressure of 760 mm Hg, the added pressures of 0, 100, 200, and 300 mm Hg correspond to TDG percent saturations of 100%, 113.2%, 126.3%, and 139.5%, respectively. The results of these calibrations for water year 2000 are shown in figure 3. Almost all of the calibrations were within 1-percent saturation of total dissolved gas. One outlier, for 0 mm Hg added pressure at Skamania, was 5.3 percent larger than expected. This result indicated that the sensor was defective, and it was replaced.

If any of the measurements differed more than 3 mm Hg from the primary standard, the sensor was calibrated at two points, barometric pressure and barometric pressure plus 200 mm Hg. Then the calibration of the TDG sensor was checked a second time according to the procedure above to be sure that it was correctly calibrated at the various pressures.

After the pressure check and calibration (if needed) of the TDG sensor, the dried membrane was reattached to the sensor, and the sensor guard was screwed back on the probe. Then another test was done for responsiveness to supersaturation with "club soda" (carbonated water) (lower half of fig. 2, item 3). Again, if the membrane/sensor was operating correctly, the measured TDG rose to at least 1,000 mm Hg in 2 or 3 minutes. If the response was not this large, the membrane was replaced. This second test, with club soda, was done because the process of installing the sensor guard had been found to abrade the TDG membrane, so the test ensured that the membrane was still functional.

The final step was to inspect the inside of the membrane for moisture (lower half of fig. 2, item 5.) If no moisture was visible, the TDG probe was labelled as ready for field deployment.

In addition to the TDG probes that were calibrated for replacement in the field each 2 to 3 week calibration interval, one TDG probe was calibrated every 2 to 3 weeks for use in the field as a secondary standard. This was the probe designated "Lab" on figure 3. The TDG sensor was calibrated in the manner described above, and, additionally, the temperature calibration was checked in a water bath at a temperature near to the ambient river temperature at the time. The temperature displayed for the probe thermistor was compared to the temperature as read to the nearest 0.1 degrees Celsius with a NIST-traceable mercury thermometer. The TDG temperature probe for the "Lab" Hydrolab could not be adjusted to display the correct temperature, so the needed adjustment (if any) was recorded for later use during the field calibrations.

Calibration of Instruments in the Field

The fixed station monitors were calibrated every 2 weeks from March 10 to September 15, 2000, and every 3 weeks for the remainder of the year, at which time Warrendale and Bonneville forebay were the only sites in operation. The general procedure was to check the operation of the field probe without disturbing it, then replace the field probe with one that had been recently calibrated in the laboratory (as described above) and check the operation of the newly deployed field probe. The details of the field procedure follow.

The first step was to fill out the heading of the field sheet (fig. 4) indicating site, date and time, weather conditions, and identification of the equipment at the site. Then the "LAB" TDG probe (the secondary standard) was placed in the river at a location adjacent to the field probe (fig. 4, item 1). The instrument shelter (a waterproof metal enclosure) was checked to ensure that the vent was unobstructed so that the barometer could effectively measure the ambient barometric pressure (fig. 4, item 2).

A palmtop computer was connected to the DCP, allowing for data retrieval and program adjustment and

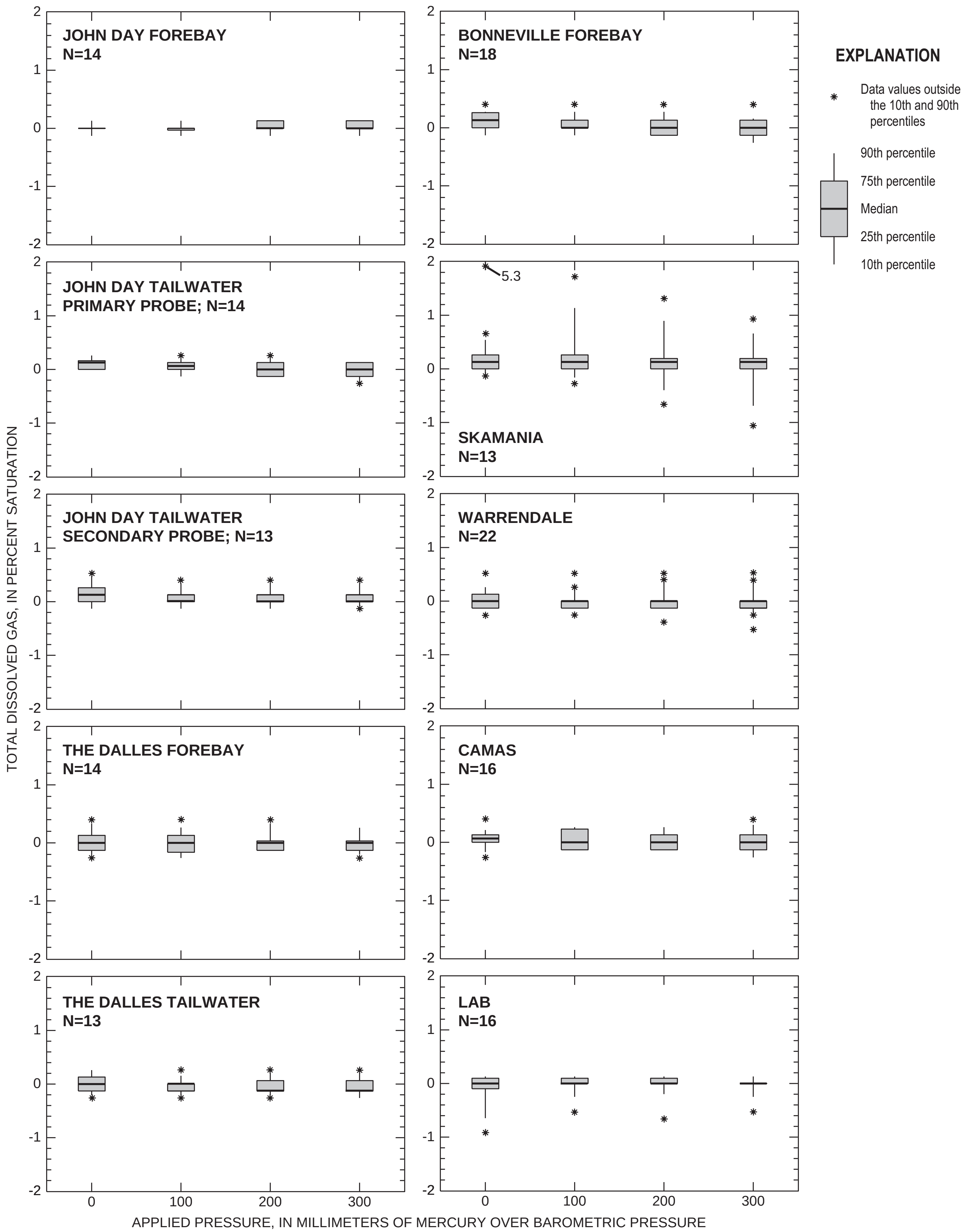

Figure 3. Accuracy of total dissolved gas sensors when compared to a primary standard after field deployment. (Total dissolved gas value from primary standard minus value from field total dissolved gas probe.)

HYDROLAB TDG FIELD INSPECTION/CALIBRATION SHEET (1/00 version)

----- USGS Portland, Oregon (503)251-3200 ---------------------

Site ID: BON Date: 5-24-00 Arrive time: 1020

Personnel: Brooks Purpose: calibration

Weather: sunny Air temperature: 20.8 C

Observed spill conditions: All gates

DCP# 37409 TBO# 19

Lab Hydrolab # 33674 Date last cal. 5-18-00

Lab Barometer ID DQT Date last cal. 5-18-00

1. **WITHOUT MOVING THE OLD FIELD HYDROLAB, PLACE LAB HYDROLAB IN RIVER AT DEPTH OF OLD FIELD HYDROLAB** Time: 1025

2. IS SHELTER VENT OBSTRUCTED (Y/N): N

3. **CONNECT COMPUTER AND CHECK DCP**
   Dump logged data to file: 5/12/2000 .LOG (3 kb)
   Most recent logged data: time 1700 baro 763 temp 14.64 depth 17.46 Pt 836
   DCP clock time: 17:33:30 GMT time (watch): 17:33:29
   Reset clock (Y/N): N
   Recording status (check one): X ON&TX, ___ ON&FT, ___ ON, ___ OFF
   Antenna angle approx. 35-40 degrees to horizon (Y/N): Y
   Antenna direction approx. 180 degrees - south (Y/N): Y
   Battery minimum: 13.26 VDC Battery maximum: 13.34 VDC
   Next transmission 18:11:10 GMT Error messages (Y/N): N (log in notes)
   Clear status (Y/N): Y

4. **CHECK POWER AND CHARGING SYSTEM WITH MULTI-METER**
   AC (at outlet): 120.0 VAC
   DISCONNECT battery IF next transmission NOT imminent
   BATTERY (at poles): 13.33 VDC
   REGULATOR (at leads to battery from DCP = 13.8VDC/.75A): 13.29 VDC
   RECONNECT battery, then disconnect right side DCP bus bar
   SOLAR PANEL OR AC/DC CONVERTOR (at PWR IN screws): 13.76 VDC
   RECONNECT bus bar

5. BAROMETRIC PRESSURE

   763 mm - 760 mm = 3 mm IF |*5*| > 10mm, replace TBO
   (Lab BP) (TBO BP) (*5*)

   763 mm - 764 mm = -1 mm
   (Lab BP) (DCP BP) (Back Shift)

   Reset DCP Old offset 0.001 New offset 0 Time: 1037

6. TEMPERATURE Uncorrected Lab WT = 14.61 C

   14.71 C - 14.67 C = +.04 C Time: 1038
   (Corrected Lab WT) (Old Field Hyd WT) (Back Shift)

NOTES: ____________________

Figure 4. Field inspection/calibration sheet.

7. AFTER A MIN. OF 15 MIN. IF LAB & OLD FIELD HYD PT READINGS HAVE NOT CHANGED 1 MM./2 MIN. AFTER SHAKING **LAB** HYDROLAB OR IF LAB & OLD FIELD HYD ARE CHANGING BUT DIFFERENCE IS CONSTANT:

855 mm - 853 mm = 2 mm   Time: 1054

Lab Hyd PT   Old Field Hyd PT   Back Shift

855-763=92/23

current is shifting lab probe up & down a few feet

Time	Lab Pt	Old Fld Pt
1039	868	836
1045	860	851
1047	857	852
1049	856	853
1050	853	853

8. **CALCULATE MINIMUM SENSOR COMPENSATION DEPTH (MSCD)**
   (Lab PT - Lab BP) / 23 = 4.00 ft.
   Sensor depth at arrival: 17.46 ft.

9. IF OLD FIELD HYD NOT AT OR BELOW MSCD, LOWER OLD FIELD AND LAB HYD TO MSCD. ALLOW TO STABILIZE AND RECORD OLD LAB AND FIELD PT AND WT IN NOTES.

10. **REMOVE OLD FIELD HYDROLAB FROM RIVER**   Record Old Fld. Hydrolab # 33768   Time: 1055

11. **CHECK DEPTH PARAMETER ON OLD FIELD HYDROLAB**
    Depth reading (Hydrolab out of the river) -0.07 ft   Time: 1056

12. **CONNECT NEW FIELD HYDROLAB, CALIBRATE DEPTH PARAMETER, CHECK Pt IN AIR**
    New Field Hydrolab # 37599   Last caibrated 5-18-00
    Depth reading before zeroing -0.13 ft Reset depth to 0.0 ft
    Record Pt reading in ambient air 761 mm   Time: 1057

13. **DEPLOY NEW FIELD HYDROLAB IN RIVER AT 15' OR MAXIMUM DEPTH OF SENSOR HOUSING**
    Sensor depth: 16.32 ft   Time: 1103

14. TEMPERATURE   Uncorrected Lab WT = 14.62 C

    14.72 C - 14.66 C = +.06 C
    Corrected Lab WT   New Field Hyd WT

    Reset DCP   Old offset 0   New offset +.1   Time: 1106

15. AFTER A MIN. OF 15 MIN. IF LAB & NEW FIELD HYD PT READINGS HAVE NOT CHANGED 1 MM./2 MIN. AFTER SHAKING **NEW FIELD** HYDROLAB OR IF LAB & NEW FIELD HYD ARE CHANGING BUT DIFFERENCE IS CONSTANT:

    852 mm - 855 mm = -3 mm   Time: 1124
    Lab Hyd PT   New Field Hyd PT   *15*

Time	Lab Pt	New Fld Pt
1104	853	855
1122	852	856

    IF |*15*| is > 10 mm, replace new Hydrolab with a backup, or do A and B

A. TEST NEW FIELD AND LAB HYD. WITH CLUB SODA:
   New Fld. Hyd. ___________ mm Time: ________
   Lab Hyd. ___________ mm Time: ________

B. TEST NEW FIELD AND LAB HYD. WITH PRESSURE GAGE AND CHAMBER:
   New Fld. Hyd. ambient___________ mm; plus 200mm__________ mm Time: ________
   Lab Hyd. ambient___________ mm; plus 200mm__________ mm Time: ________

IF NEW FLD. HYDROLAB FAILS EITHER TEST, REPLACE IT WITH A BACKUP HYDROLAB.
IF LAB HYDROLAB FAILS EITHER TEST, USE A BACKUP HYDROLAB TEMPORARILY AS THE LAB METER.

16. **CHECK DCP OFFSET FOR Pt = ZERO**   Y/N: Y

17. **SAVE SETUP, CHECK RECORDING STATUS = "ON&TX", DISCONNECT LAPTOP** Y/N: Y

Equipment changed other than Hydrolab (Y/N, item): N, ____________   End time: 1126

NOTES: ____

Page 2

Figure 4. Field inspection/calibration sheet—Continued.

checking (fig. 4, item 3). The data that were logged by the DCP since the last visit were downloaded to the palmtop computer so they could be available in the event that any data were not transmitted by the satellite system. The clock in the DCP was checked and adjusted, if necessary. Antenna alignment and recorded battery voltages were checked and recorded.

The power and charging systems were checked using a digital multimeter (fig. 4, item 4). Some of the sites had 120-volt alternating-current (AC) power service; the voltage of those supplies was checked. With the battery disconnected, its voltage was measured, and the circuit that charges the battery (the regulator) was checked. Finally, the battery was reconnected, and the voltage output of the solar panel or AC/DC converter was checked before its input to the voltage regulator.

The field-deployed electronic barometer was checked and adjusted, if necessary (fig. 4, item 5). The measurement from the secondary standard aneroid barometer ("Lab BP" on figure 4) was compared to the measurement made by the field electronic barometer and displayed by the DCP ("DCP BP" on fig. 4). If there was a difference, the back shift was applied to change the offset value in the DCP program. After this step, the DCP would display the same barometric pressure (to the nearest millimeter of mercury) as the secondary standard, the aneroid barometer. The results of the field calibrations of the electronic barometers at the fixed stations are shown in figure 5. Most of the time, the field barometer was within 1 mm Hg of the secondary standard. At The Dalles forebay site, the spread of data was widest—between plus and minus 2 mm Hg. This probably was the result of a variable signal from the electronic barometer, which resulted in the offset being adjusted one way on one calibration visit and the other way on the next calibration visit.

The performance of the field temperature sensor was documented (fig. 4, item 6). The water temperature measurement made by the secondary standard TDG probe ("Corrected Lab WT") was compared to the measurement made by the nearby field-deployed TDG probe ("Old Field Hyd WT"). The differences were usually less than 0.1ºC (degrees Celsius), indicating the accuracy when compared to the secondary standard (fig. 6).

Performance of the fixed-station TDG sensor was documented (fig. 4, item 7). Values of TDG obtained by the secondary standard TDG sensor ("Lab Hyd PT") were compared to the values obtained by the fixed-station TDG sensor ("Old Field Hyd PT"). For this

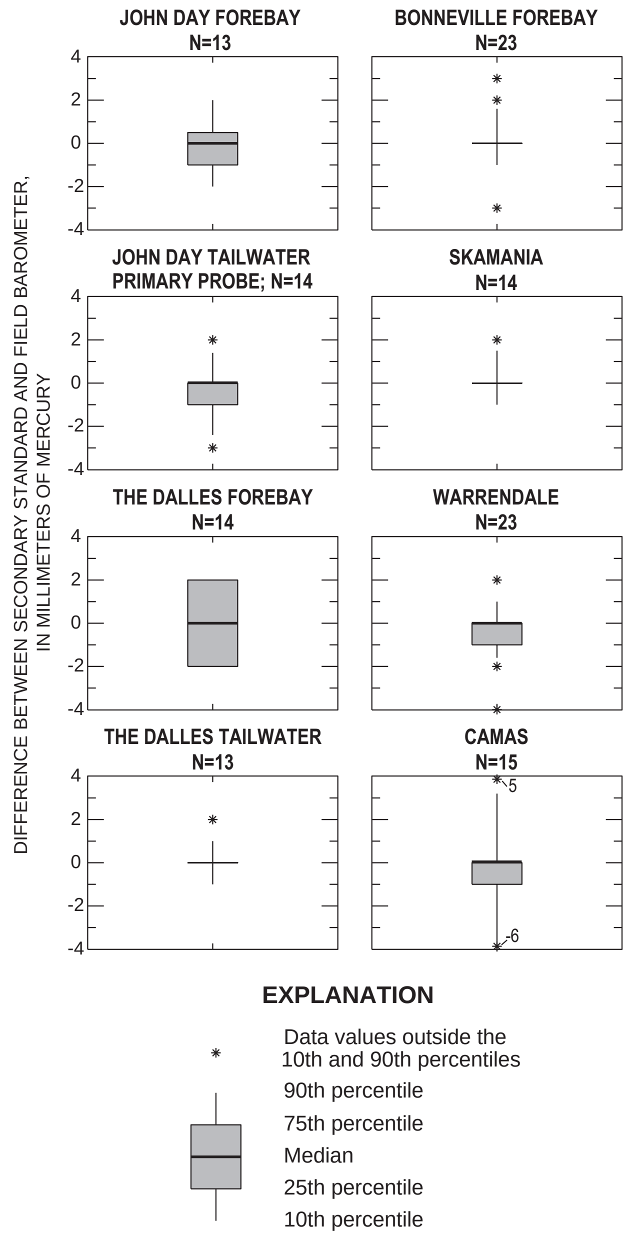

Figure 5. Difference between the secondary standard and the field barometers.

comparison, it was necessary to wait until the secondary standard reached equilibrium in the river. Usually this equilibration process took about 30 minutes and was considered to be complete when the reading for each probe did not change even 1 mm Hg for a period of 2 minutes. At most sites, there was usually less than a 1 percent TDG difference between the secondary standard and the fixed-station monitor (fig. 7.) At The Dalles site once, and at the Camas site three times, the TDG measurement from the fixed-station monitor was more than 10 percent larger than the measurement from the secondary standard (fig. 7). These were times when

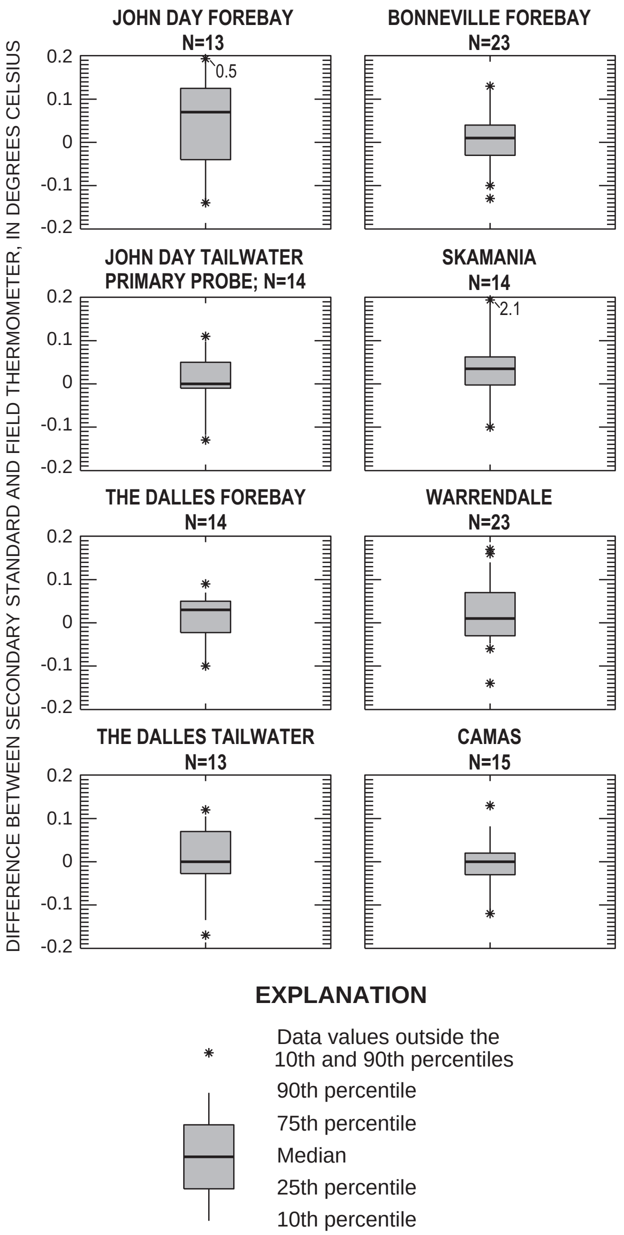

Figure 6. Difference between the secondary standard and the field thermometers.

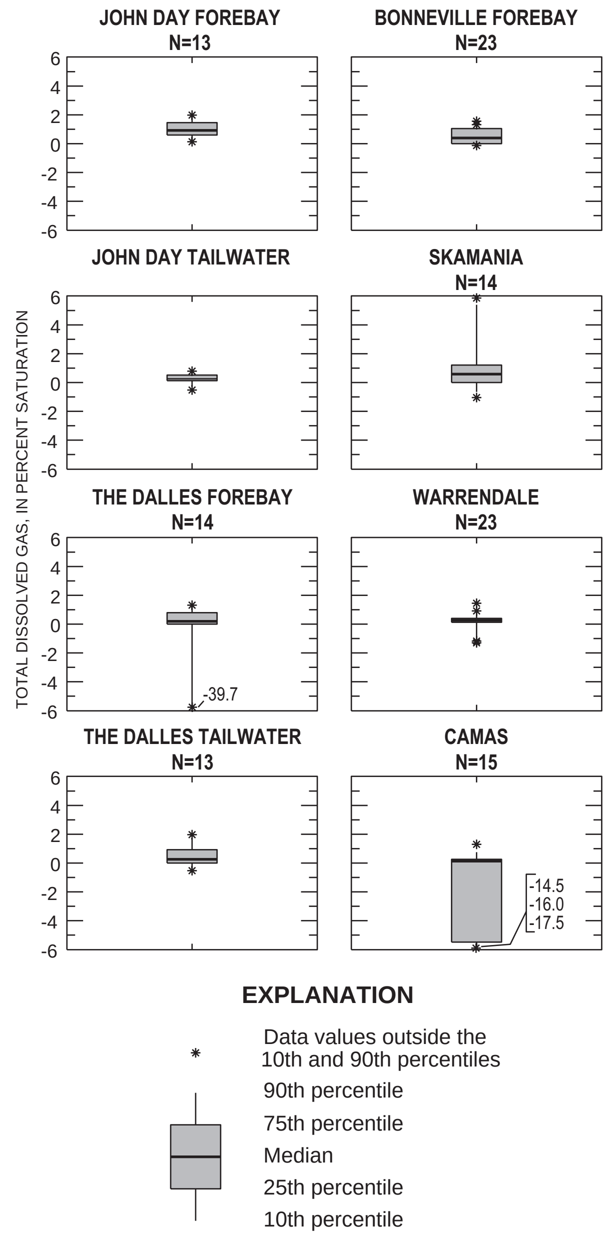

Figure 7. Total dissolved gas difference between the field probe and lab probe initially.

the TDG membrane had been broken, resulting in incorrect TDG measurements.

The minimum compensation depth was calculated and recorded (fig. 4, item 8). This depth, calculated according to a formula derived from Colt (1984, page 104), is the depth above which degassing will occur, due to the decreased hydrostatic pressure. In order to measure TDG accurately, the probe must be deeper than the calculated compensation depth. If the probe was not below minimum compensation depth and it was physically possible to have it that deep, the TDG was measured at the larger depth (fig. 4, item 9).

The probe from the fixed station was removed from the river and the depth parameter was checked when it was above the water surface (fig. 4, items 10 and 11). The depth reading usually differed from zero by about 0.1 or 0.2 feet. These differences were due to the fact that the depth sensor on the TDG probe was not vented to the outside atmosphere, so that changes in barometric pressure affected the measured depth of the TDG probe.

The newly calibrated TDG probe was connected to the fixed-station equipment, the functions of depth and TDG measurement were checked, and the zero point for depth measurement was calibrated (fig. 4, item 12).

The TDG probe was allowed 5 to 10 minutes to equilibrate in the river then the temperature measurement function was checked and calibrated (fig. 4, item 14). Using the electronic offsets in the DCP, the measurement made by the newly calibrated TDG probe was made to read the same temperature as measured by the secondary standard for temperature (the laboratory-calibrated TDG probe).

The final field calibration step (fig. 4, item 15) was to check the TDG measurement in the river made by the newly calibrated fixed-station probe against that made by the secondary standard (the laboratory-calibrated TDG probe). These two values usually were within 2 percent TDG of each other (fig. 8).

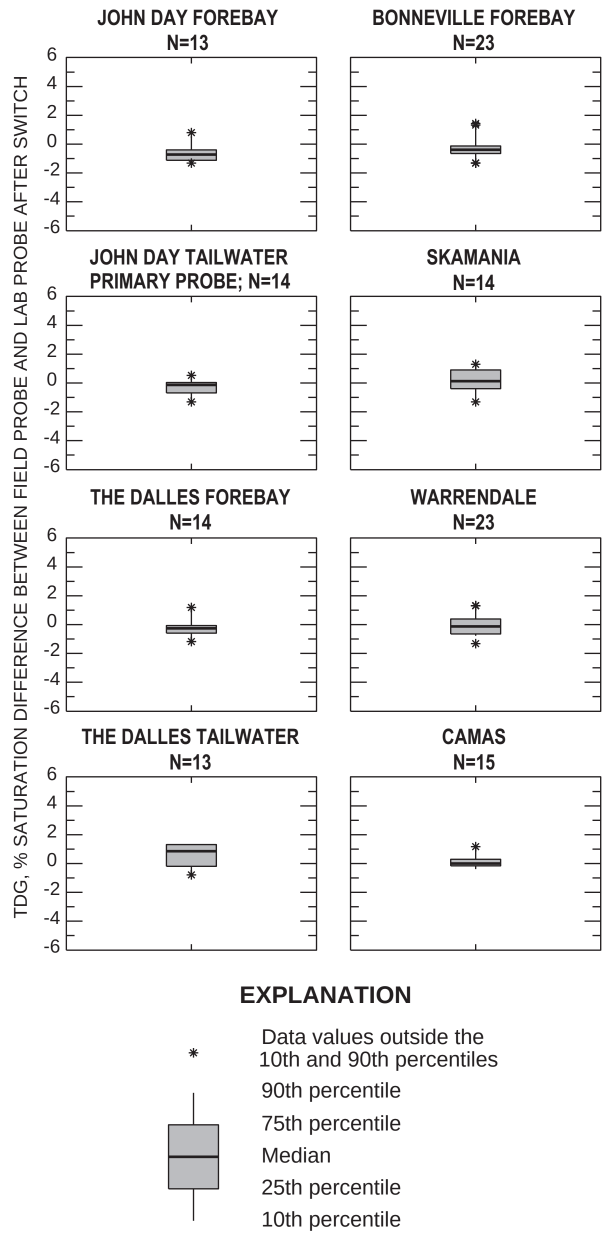

Figure 8. Total dissolved gas difference between the field probe and lab probe at the end of field calibrations.

Daily Quality-Assurance Checks

Each morning, the performance of the TDG fixed stations was evaluated and e-mail concerning the status of the network was sent to involved parties, including USACE. Figures 9–11 are examples of the materials used for the daily quality-assurance checks. Figure 9 shows a checklist summarizing intersite comparisons. Figure 10 is an example of 1 of 33 pairwise graphs of TDG, barometric pressure, and temperature data from adjacent sites made during the spring and summer spill season; 1 additional graph showed the 2 TDG measurements made at the John Day tailwater site. Data for graphs of intersite comparisons were from the USGS ADAPS database, current to approximately 0600 hours on the day of the check. Also included were data from the USACE Web site showing spill and total flow below the dams at John Day, The Dalles, and Bonneville. These data were included to help explain variations of TDG that could be related to the changing operations of the dams above the fixed-station TDG monitors. For example, figure 11 illustrates the effects of changes in spill over the John Day Dam on TDG measured at the John Day tailwater site.

These quality-assurance materials were valuable for evaluating the status of the monitoring network. If data were completely missing from one site, the satellite downlink data were checked to see if signal strength, transmission time, or battery voltage data were anomalous for previous transmissions.

On occasion during these daily checks, the TDG values were observed to suddenly increase and stay constant at a larger value, without a corresponding increase in spill at the dam above the site. In these cases, the problems were caused by a tear or hole in the TDG membrane, which allowed water pressure to influence the TDG sensor, which should have been exposed only to the air inside the tubular TDG membrane.

When this happened, an “emergency” field trip was made to resolve the problem. In the case that there were data from a site that were known to be incorrect as a result of a damaged membrane or for any other reason, this was noted in the daily e-mail to the interested parties mentioned previously.

CHECKLIST FOR TDG DAILY CHECKS - attach to daily graphs

Date 6/23/00 Checked by Tanner

Check the 33 intersite comparison graphs back to the last day checked.
(For example, check back to Friday on Monday).

✓ Pt - No more than 25% of the hourly values are missing or anomalous
(Intersite comparisons differ < 20 mm Hg unless spill explains difference)

✓ B.P. - No more than 25% of the hourly values are missing or anomalous
(Intersite comparisons differ < 14 mm Hg)

If these conditions are not met, an emergency trip needs to be taken within the next 48 hours.

✓ Temp. - Check for intersite variations > 2.0 deg C, note to COE, but
no emergency trip is needed.

Y or (N) Is replot needed to clearly see data variations on any plot?
If yes - replot data and put the new plot with the daily check.

Y or (N) Are any data missing from ADAPS but present at COE website?
If yes - put COE data with site file.
- immediately contact our computer section to restore data to ADAPS if possible.

Y or (N) Were any graphs marked to explain or note any potential anomalies?
If yes - make a copy and put copy in site file.

X Send email to COE describing site status, including planned emergency trips.

If any site is other than satisfactory, include the hour of missing or questionable data, and put a copy of the email in site file.

Figure 9. Checklist for total dissolved gas daily quality-assurance checks.

Data Workup and Archive

Periodically, and at the end of the fiscal year, data for each TDG fixed-station were reviewed in-house and documented on paper files and in the USGS database. Tables and graphs of hourly value data were prepared for TDG, barometric pressure, and water temperature for each month for which data were collected. These tables and figures were screened using intersite comparisons between adjacent sites and monthly graphs of spill from appropriate dams. Any incorrect data were deleted from the database. Common causes of incorrect data included elevated TDG measurements due to torn TDG membranes (mentioned above) and missing value codes from the satellite transmissions that were interpreted by the USGS database as large measured values. An electronic file of data to be deleted was prepared for USACE.

In one case, at the Skamania site from August 30 to September 15, 2000, a linear shift was applied to the TDG data due to the gradual failure of the TDG sensor. The shifted data were incorporated into the USGS database and the same shifted data were supplied to USACE.

Ancillary data and information were also documented in paper files. Data for battery voltage after each satellite transmission were graphed on a monthly basis in order to track any problems with data transmission

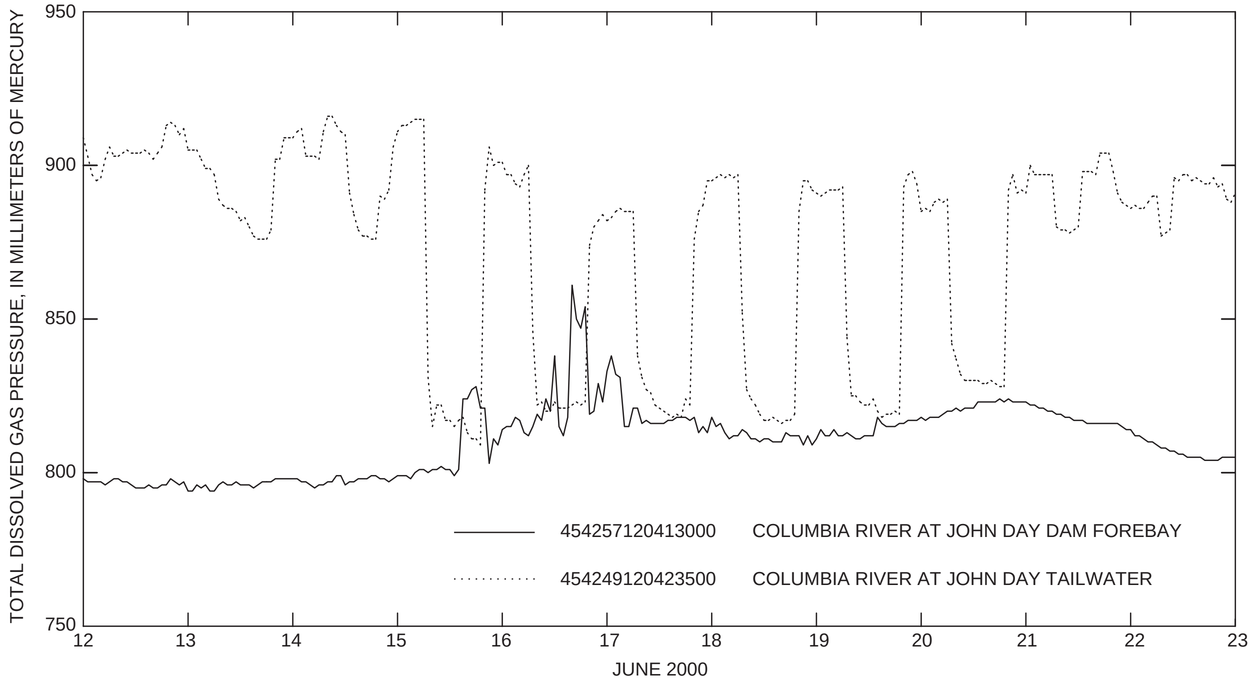

Figure 10. Total dissolved gas pressure above and below John Day Dam**.**

TOTAL DISSOLVED GAS REPORT FOR JOHN DAY TAILWATER
starting at 0405 22 jun 2000

DATE	TIME	WA TM DEG F	BARO PRES	TD1 GAS PRES	TD2 GAS PRES	GAS(1) %	SPILL S	TOT R
0622	0500	62.7	760.0	897.0	890.0	118.03	090.4	153.5
0622	0600	62.7	759.0	897.0	888.0	118.18	083.4	147.6
0622	0700	62.7	760.0	880.0	879.0	115.79	054.3	160.6
0622	0800	62.7	760,0	879.0	875.0	115.66	054.2	176.7
0622	0900	62.8	761.0	879.0	874.0	115.5l	054.2	181.7
0622	1000	62.8	761.0	878.0	873.0	115.37	054.3	185.8
0622	1100	62.8	759.0	879.0	873.0	115.81	058.7	194.9
0622	1200	62.9	760.0	880.0	873.0	115.79	063.9	211.7
0622	1300	62.9	759.0	898.0	887.0	118.31	070.3	230.4
0622	1400	63.0	759.0	898.0	892.0	118.31	070.3	264.1
0622	1500	63.1	760.0	898.0	891.0	118.16	070.5	236.0
0622	1600	63.1	760.0	897:0	891.0	118.03	073.4	235.0
0622	1700	63.1	759.0	904.0	896.0	119.10	081.4	275.8
0622	1800	63.1	760.0	904.0	896.0	118.95	083.0	274.7
0622	1900	63.1	759.0	904.0	895.0	119.10	084.0	264.4
0622	2000	63.1	760.0	898.0	891.0	118.16	136.8	233.5
0622	2100	63.2	761.0	891.0	882.0	117.08	122.2	209.8
0622	2200	63.2	761.0	888.0	880.0	116.69	122.2	207.2
0622	2300	63.1	759.0	887.0	878.0	116.86	124.5	206.8
0623	000	63.1	761.0	886.0	880.0	116.43	122.1	203.0
0623	0100	63.1	760.0	887.0	880.0	116.71	122.1	200.4
0623	0200	M	M	M	M	U	118.3	190.7
0623	0300	M	M	M	M	U	118.3	200.2
0623	0400	M	M	M	M	U	116.4	200.4

STATUS=M, data missing due to lag time between data collection and transmission
STATUS=U, data unavailable (not calculable)

Figure 11. Example data table from U.S. Army Corps of Engineers Total Dissolved Gas Reports Web page (http://www.nwd-wc.usace.army.mil/report/tdg.htm).

due to low battery voltage. The recorded probe depth was also graphed. E-mail correspondence referring to each site was also archived in the corresponding site folder.

SUMMARY OF DATA COMPLETENESS AND QUALITY

Year-end summaries of water year 2000 TDG data completeness and quality are shown in table 2. Data in this table were based on the amount of hourly TDG data and barometric pressure data that could have been collected during the scheduled monitoring season. At all stations, more data were collected than was scheduled because the monitors were set up early to ensure correct operation. Because TDG in percent saturation is calculated as total dissolved gas pressure, in millimeters of mercury, divided by the barometric pressure, in millimeters of mercury, multiplied by 100 percent, any hour with missing TDG pressure data or missing barometric pressure data was counted as an hour of missing data for TDG in percent saturation. The percentage of real-time data received shown in table 2 represents the data that were received via satellite telemetry at the USGS downlink. The USACE downlink operated independently, but the amount and quality of the data were very similar. At each station, 98 percent or more of the data were received real-time by the USGS downlink, with an overall average of 99.6 percent. Problems with the amount of real-time data received were usually due to malfunction or misprogramming of the data-collection platform.

The collection of water temperature data had fewer complications than did the collection of TDG and barometric pressure data. There were only a few hours of missing or incorrect temperature data, except for instances where all data parameters were missing due to problems with the DCP.

TDG data were considered to meet quality-assurance standards if they were within 1 percent TDG of the expected value, based on calibration data and ambient river conditions at adjacent sites. The percentage of real-time TDG data passing quality assurance is shown in table 2. The lowest percentage for a station was 95.3 percent at Skamania, but all of the missing data was eventually restored to the database. The overall average of real-time data passing quality-assurance standards was 98.5 percent. Most problems with meeting quality-assurance standards were due to membrane failure—leaking or tearing of the TDG membrane.

QUALITY-ASSURANCE DATA

Duplicate data for John Day tailwater were collected for TDG only. Data between the two instruments compared well, as depicted on figure 12, which shows how the two probes responded to daily changes in spill at the John Day Dam. The greatest differences occurred at times when gas levels changed rapidly, as a

Table 2. Total dissolved gas data completeness and quality, water year 2000
[TDG, total dissolved gas]

Abbreviated station name	Planned monitoring, in hours	Percentage of real-time TDG data received	Percentage of real-time TDG data passing quality assurance
John Day forebay	4,032	99.4	99.4
John Day tailwater			
Main probe	4,032	99.9	99.9
Duplicate probe	4,032	99.9	98.7
The Dalles forebay	4,032	99.5	97.7
The Dalles tailwater	4,032	100.0	100.0
Bonneville forebay	8,784	98.3	98.2
Skamania	4,560	100.0	95.3
Warrendale	8,784	99.9	99.3
Camas	4,560	99.8	98.0
Average		**99.6**	**98.5**

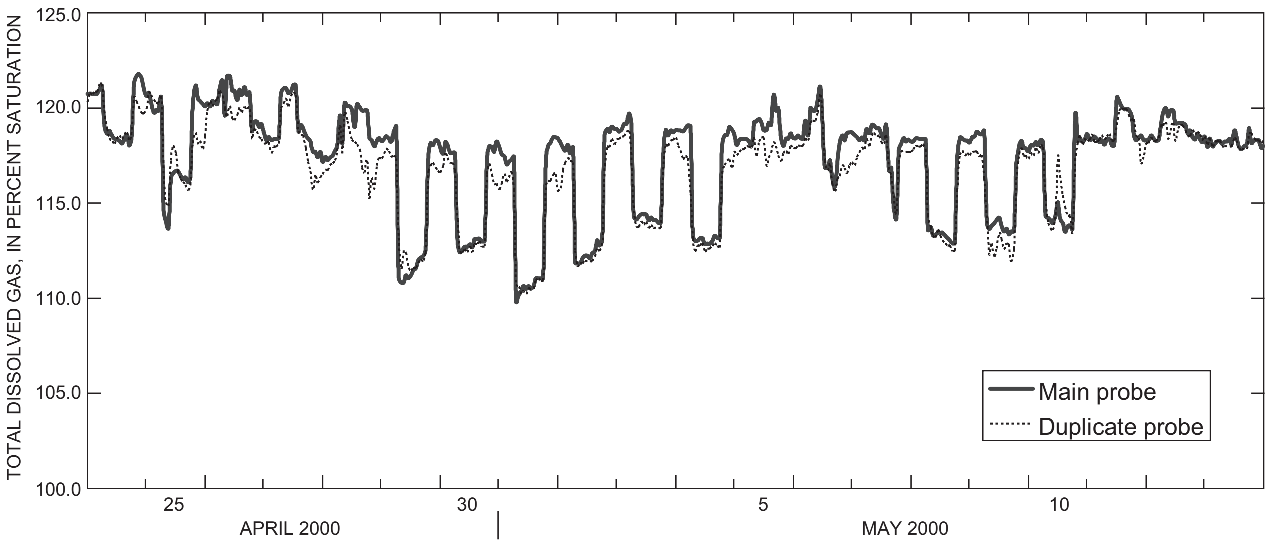

Figure 12. Selected total dissolved gas data at the main and duplicate probes at John Day tailwater.

result of each probe responding at a different rate. Future deployment of redundant probes should have paired membranes with the same age and use, to reduce differences in response time.

A slight bias existed between the two probes as depicted by figure 13, which represents 4,317 hourly values from March 23 to September 18, 2000. The duplicate probe was 1 foot higher in the water column and tended to read lower than the main probe. A likely cause of this bias may be a reduced flow over the membrane on the duplicate probe. Perforations in the housing were originally intended for one probe located at the end of the housing. This concern will be eliminated by installing two adjacent TDG sensors on the same Hydrolab.

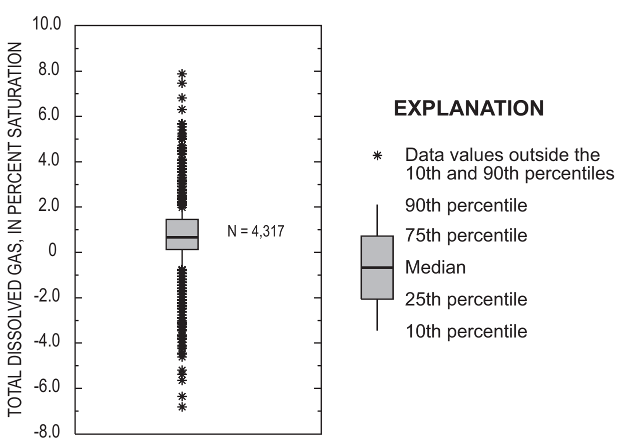

Figure 13. All of the total dissolved gas data at the main and duplicate probes at John Day tailwater.

Duplicate TDG and water temperature data were collected at the John Day forebay from 4/5/2000 at 1600 hours to 4/12/2000 at 1400 hours. The duplicate probe was mounted approximately 6 feet horizontally from the main probe at the same depth. The duplicate data were collected to confirm the rapid changes in temperature and TDG above the John Day Dam that did not occur below the dam, as depicted in figures 14 and 15. TDG and water temperature measured by the main probe compared well with the duplicate probe. Based on the strong correlation between the two units, the rapid changes in water temperature and TDG appear to be real and not a problem with instrumentation. The cause of these rapid changes is not known at this time; however, it is suspected that water near the probes is not well mixed and occasionally water in the vertical section is transported across the face of the dam by certain spill patterns that cause poorly mixed water to flow over the probes.

SITE-SPECIFIC CONSIDERATIONS

Even though the same type of electronic equipment and instruments were used at each site, there were differences among the sites in the physical setup and environment of equipment. Some sites were at a river location with limited depth, some had greater circulation of water past the probe, and some were prone to damage by insects. These site-specific considerations are summarized below for each of the eight sites.

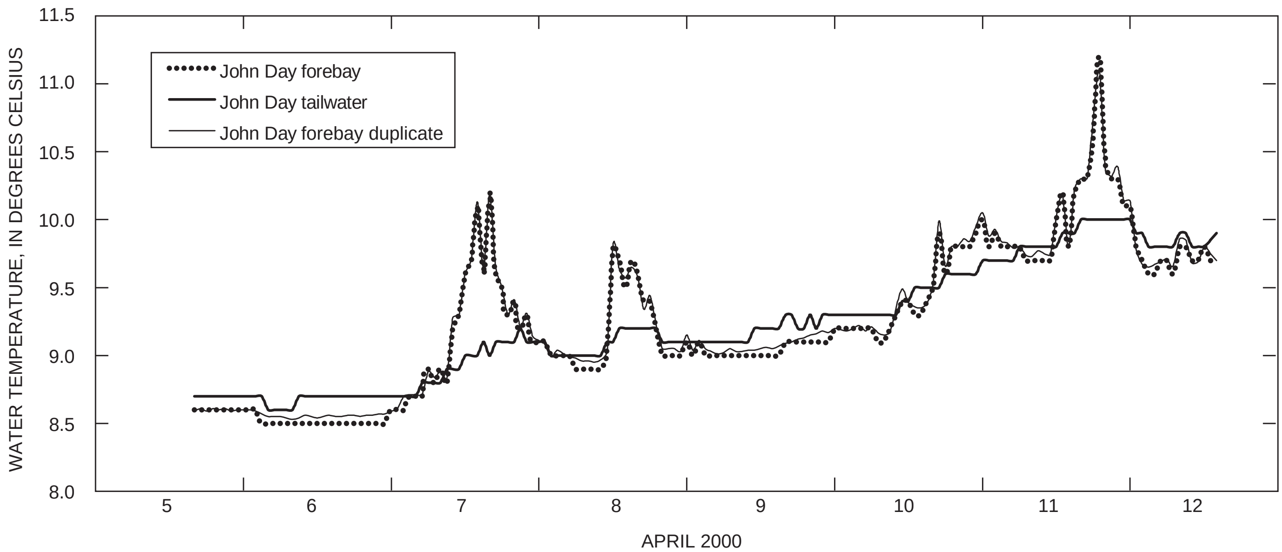

Figure 14. Duplicate water temperature data at John Day forebay and water temperature data at John Day tailwater.

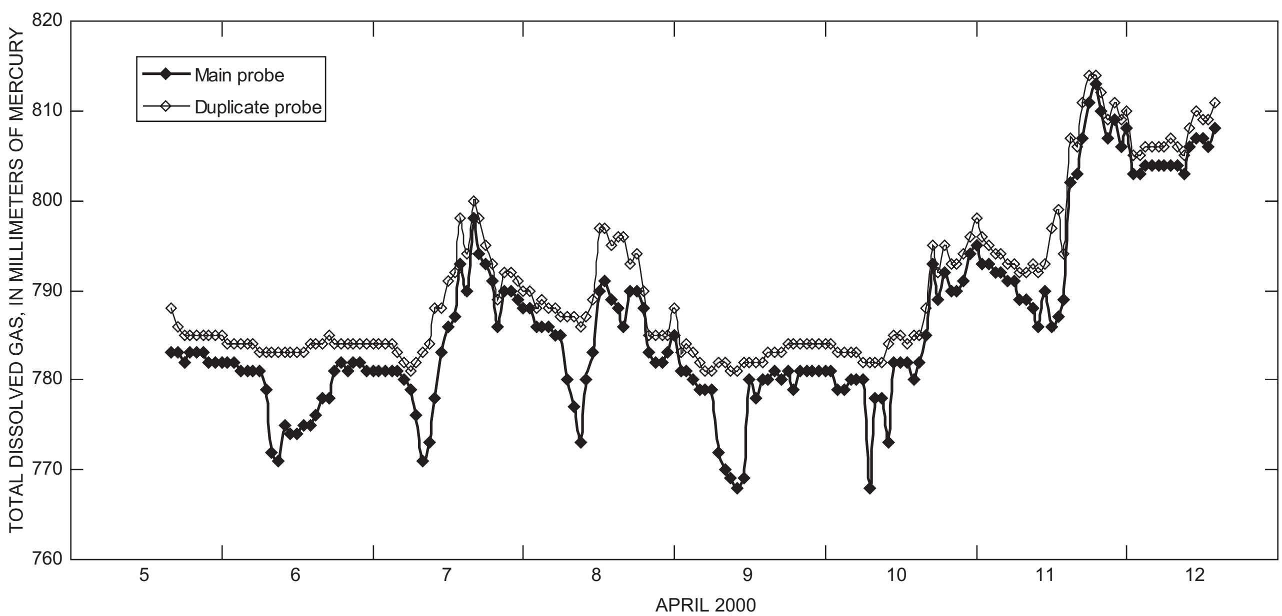

Figure 15. Duplicate total dissolved gas data at John Day forebay.

Camas

At the Camas site, there were three separate occasions (June 29, July 23, and July 31, 2000) when the TDG membrane was pierced by aquatic insects, which were observed inside the probe housing. When this happened, the hole in the membrane allowed water pressure instead of dissolved gas pressure to act on the TDG pressure sensor. As a result, the measured values for TDG rose suddenly to about 1,000 mm Hg, even though there was not an unusual amount of spill from Bonneville Dam, which is upstream of the Camas site. This condition was diagnostic of a broken membrane, and accordingly, an emergency field trip was made to replace the probe with a newly calibrated probe. During the third trip due to a damaged membrane, screening was added to the probe to exclude insects, and the problem did not reoccur. TDG data that were lost due to this type of damage were not recoverable because there is no way to know precisely what would have been recorded at those times.

Also at the Camas site, the barometer was adjusted incorrectly, resulting in a bias of -5 mm Hg for 21 hours beginning on June 5, 2000, at 1200 hours. The barometer was readjusted, and the 21 hours of data were corrected in the database.

Skamania

At Skamania, a newly calibrated probe was placed in the river on August 30, 2000, at 1036 hours. The following day, scheduled spill ended for the season at Bonneville Dam, just upstream. As a result, the TDG was expected to decrease at the Skamania site, and a decrease was observed. However, the TDG eventually decreased to levels lower than would be expected. When the probe was inspected, it was found to have a faulty sensor, which accounted for the TDG readings being too low. Subsequently, a linear shift was applied to the data, with no shift for August 30 at 1100 hours, and shifts increasing until a final shift of +56 mm Hg on September 18 at 1100 hours. This was an example of data being transmitted in a real-time manner, but not being correct. Further, in this case, the data were correctable because the gradual decline in TDG readings (with no change in spill) was consistent with a gradually failing TDG sensor.

Warrendale

At Warrendale, there was a faulty TDG sensor, which resulted in erratic TDG values from February 29, 2000, at 1300 hours until March 2, 2000, at 0800 hours. The sensor was replaced, but there was no way to correct the data in question, so it was deleted from the database.

Compensation depth for TDG measurement is the depth above which degassing will occur. In order to measure TDG accurately, the probe must be deeper than the compensation depth, which is calculated as [TDG pressure, in millimeters of mercury, minus barometric pressure, in millimeters of mercury] divided by 23 (a constant). This equation was based on a formula derived from Colt (1984, page 104). If the probe is above the minimum compensation depth, the measured TDG may be less than it would be if measured at a greater depth.

The compensation depth can be calculated for any given percent saturation of TDG if an assumption is made for the barometric pressure. For example, if the barometric pressure is assumed to be 760 mm Hg, and the TDG level is 120%, the TDG pressure would be 912 mm Hg (120% of 760 mm Hg), and the compensation depth would be [912 - 760]/23 = 6.6 feet. Using the same assumption for barometric pressure, at a TDG level of 145%, the compensation depth would be 14.9 feet. Where possible, the TDG probes were kept at a depth of 15 feet or greater.

Warrendale was the only site where the TDG probe was above the compensation depth at any time in water year 2000. After the end of the spill on August 31, 2000, the river stage had dropped, but supersaturated water remained in the river from upstream dams, resulting in the probe depth being above the compensation depth for several days (fig. 16). This was because of the physical characteristics of the site. The instruments were housed on a floating wooden dock, and the TDG probe was suspended from the dock. When the river was shallow at the Warrendale site, as it was in early September, the probe depth was about 4 feet because that was the total depth of the river below the dock at the time. In order to measure TDG at a greater depth, the probe would need to be moved to a deeper part of the river, but that was not possible because of the fixed location of the site.

Bonneville

At the Bonneville site, there were data transmission problems from January 1 to January 5, 2000, resulting in 46 hours of missing real-time TDG data. The cause of this missing data is unknown, but it may have been due to large cranes that work in the dam area, which have been known to sometimes be placed between the DCP antenna and the orbiting satellite, thus occluding the satellite. These 46 hours of TDG data were restored to the permanent database using the data logged onsite by the DCP.

From July 21 to July 25, 2000, 91 hours of data were missing from the Bonneville site due to failure of the DCP. In this case, the data were not logged onsite, so it was not possible to restore the data to the database.

The Dalles Tailwater

Only 2 hours of TDG data were missing from The Dalles tailwater site. One datum was missing due to calibration activities on July 20, 2000, and the cause of loss of the other datum is not known.

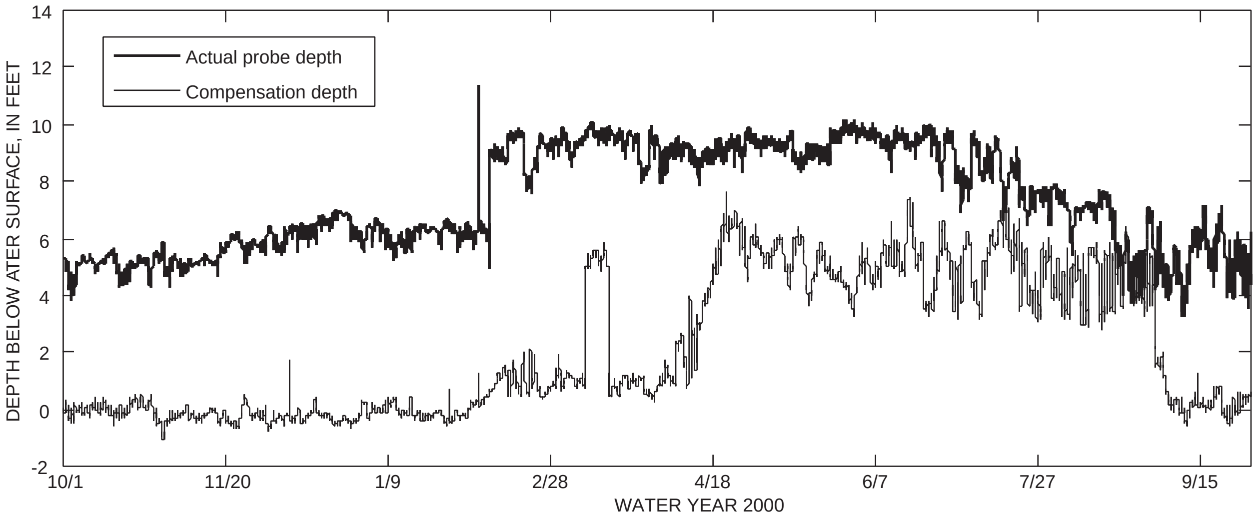

Figure 16. Compensation depth and actual probe depth at Warrendale.

The probe housing at The Dalles tailwater site is strapped to anchors along a slope of rock rip-rap. On several occasions during the monitoring season, the probe housing was raised or lowered according to the river stage. In this manner, it was possible to maintain the probe depth below the minimum compensation depth.

The Dalles Forebay

TDG data were missing from The Dalles forebay site for a 72-hour period from April 15 to April 18, 2000, due to a ruptured TDG membrane. It was not possible to restore these data to the database.

DCP problems from August 29 to September 5, 2000, were the cause of 19 hours of data that were missing in real-time. These data were later restored to the database from the data logged onsite by the DCP.

John Day Tailwater

For the duplicate unit at the John Day tailwater site, 45 hours of TDG data were missing from September 4 to September 6, 2000, due to a rupture or tear in the TDG membrane. These data could not be restored. There were only 3 hours of missing TDG data for the main unit at John Day tailwater.

John Day Forebay

Beginning on August 3, 2000, 23 hours of TDG data were missing from the John Day forebay site due to an error in reconnecting the electronic barometer during a routine calibration. These data could not be restored to the database.

On several occasions at the John Day forebay, the TDG value was observed to suddenly rise 10 or 20 mm Hg for several hours for no apparent reason. It was noted that the water temperature also rose during these times. These excursions of TDG and water temperature were observed on hot, sunny days, and it is believed that a parcel of heated water was drawn past the submerged TDG probe during spill, causing the increase in water temperature. The TDG measured at the probe would be expected to also increase, because when a gas is heated and the volume is fixed (as it is inside the TDG membrane), the pressure of the gas will increase.

REFERENCES CITED

Colt, J. 1984. Computation of dissolved gas concentrations in water as functions of temperature, salinity, and pressure: American Fisheries Society Special Publication 14, 154 p.

Jones, J.C., Tracey, D.C., and Sorensen, F.W., eds., 1991, Operating manual for the U.S. Geological Survey's data-collection system with the Geostationary Operational Environmental Satellite: U.S. Geological Survey Open-File Report 91–99, 237 p.

Tanner, D.Q., Harrison, H.E., and McKenzie, S.W., 1996, Total dissolved gas, barometric pressure, and water temperature data, lower Columbia River, Oregon and Washington, 1996: U.S. Geological Survey Open-File Report 96–662A, 85 p.

U.S. Environmental Protection Agency, 1986, Quality criteria for water: Washington, D.C., EPA–440–5–86–001.