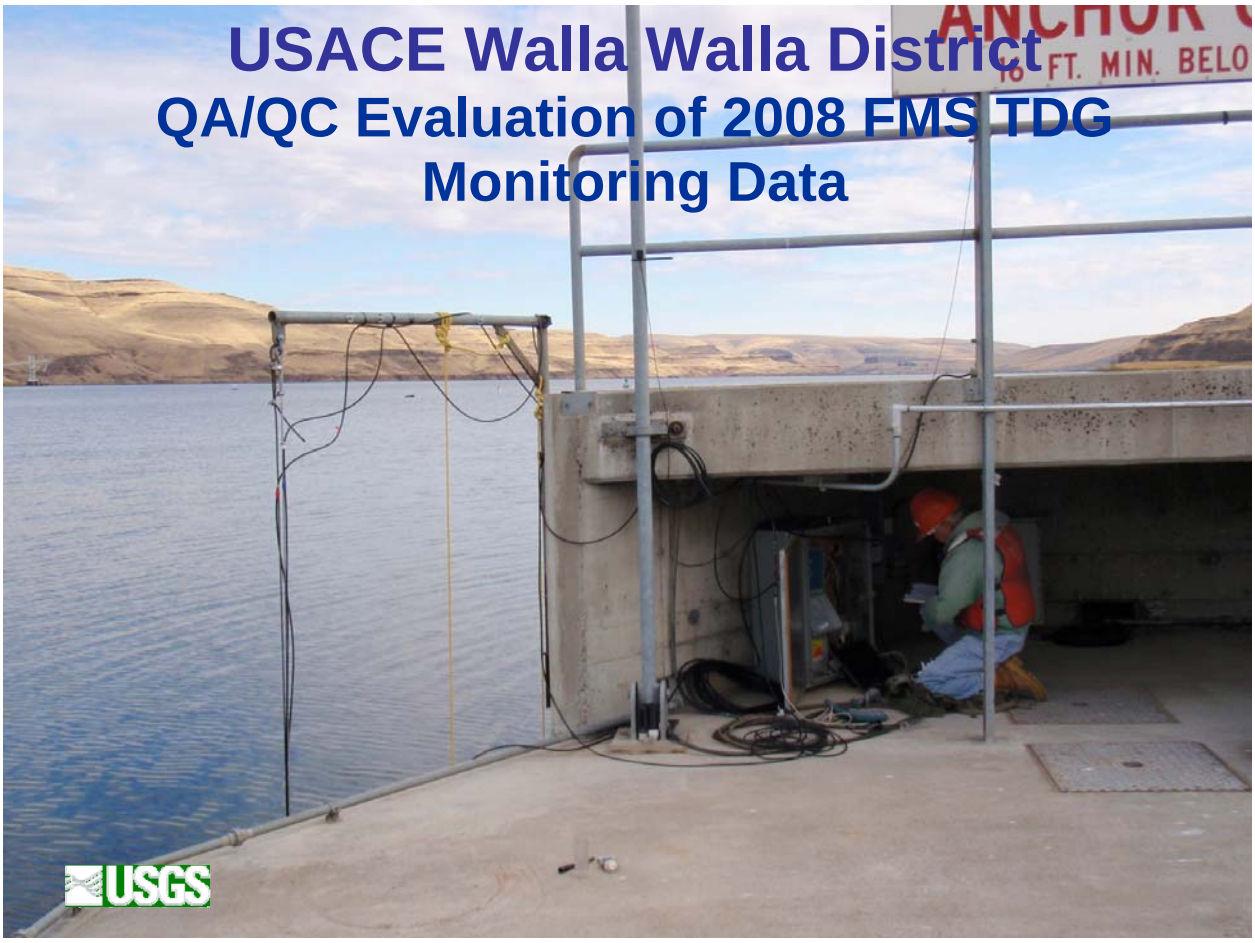
Appendix J

Walla Walla District TDG Report (Includes McNary, Ice Harbor, Lower Monumental, Little Goose, Lower Granite, and Dworshak)

Appendix J



Includes:

McNary, Ice Harbor,
Lower Monumental, Little Goose,
Lower Granite, and Dworshak

USACE Walla Walla District QA/QC Evaluation of 2008 FMS TDG Monitoring Data

Prepared by:

Hydraulic Design Section
Walla Walla District
U.S. Army Corps of Engineers
Walla Walla, Washington

Prepared for:
Northwestern Division Regional Office
U.S. Army Corps of Engineers
Portland, Oregon

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ABSTRACT

The U.S. Army Corps of Engineers (USACE), Walla Walla District (CENWW), operated fifteen fixed-monitoring system (FMS) stations (nine seasonal and six year round) for total dissolved gas (TDG), barometric pressure (BP), and temperature as part of their 2008 water-quality program. These stations are located on the Columbia, Lower Snake and Clearwater Rivers. This report provides a summary of the 2008 water-year quality assurance/ quality control (QA/QC) evaluation. Highlights include:

- 99.9% of the BP and water temperature data, and 99.6% of the TDG data were received in real-time and passed provisional QA/QC review.
- 57% of the invalid/missing BP+TDG data was due to membrane failure followed by 19% attributable to DCP failure.
- The sonde pre-deployment check had calculated median TDG and temperature values of 0.20 mmHg and 0.01 °C, respectively.
- The sonde post-deployment check revealed median TDG and temperature values of 0.20 mmHg and -0.02 °C, respectively.
- The field checks with secondary standards showed calculated median values for BP, TDG, and temperature of 0.00 mmHg, 0.0% TDG, and -0.02 °C, respectively.

1.0 INTRODUCTION

Six hydropower projects – McNary, Ice Harbor, Lower Monumental, Little Goose, Lower Granite, and Dworshak – operated by the Walla Walla District (CENWW) of the U.S. Army Corps of Engineers (USACE) are included in the basin-wide fixed-monitoring system (FMS) network. Six of the stations (*i.e.*, the tailwater stations at McNary Dam, Ice Harbor Dam, Lower Monumental Dam, Little Goose Dam, Lower Granite Dam, and Dworshak Dam) are operated throughout the year (Figure J-1; Table J-1). The remaining nine stations record data from 1 April through 31 August.

Three water-quality parameters are monitored at these facilities. One is total dissolved gas (TDG). This parameter is of interest since gas supersaturation results when air is entrained as water flows over the spillways and plunges into the stilling basin where water pressure causes the air to go into solution. The river subsequently becomes shallow beyond the stilling basin and the result is water supersaturated with TDG relative to atmospheric conditions. The U.S. Environmental Protection Agency (USEPA) has established an upper limit of 110 percent saturation for protection of freshwater aquatic life. Concentrations above this level can cause gas bubble trauma in fish and adversely affect other aquatic organisms. The State of Washington water-quality standards provide exemptions to this criterion when water is spilled for fish passage, as well as during high river discharge events (*i.e.*, flows greater than the 7Q10). WAC 173-201A-070 states that the averages of the twelve highest daily TDG values when water is spilled for fish passage can reach 115 percent in the forebays and 120 percent in the tailwaters. The one-hour maximum TDG measurement cannot exceed 125 percent. Two additional parameters that influence TDG saturation are barometric pressure and water temperature. As such, measurements for these two constituents are also recorded and stored in the database.

Measurements were completed hourly at all stations and transmitted via the Geostationary Operational Environmental Satellite Program (GOES) system to the Columbia River Operational Hydromet Management System (CROHMS) data base at the USACE Northwestern Division (CENWD) office in Portland, Oregon every hour or every four hours depending on the data collection platform (DCP) at the station. The CENWD website is the official U.S. Government source for the entire total dissolved gas monitoring system (TDGMS) and can be accessed at http://www.nwd-wc.usace.army.mil/report/total.html.

2.0 PURPOSE AND SCOPE

The purpose of gas monitoring is to provide managers, agencies, and interested parties with near real-time data for managing stream flows and TDG levels downstream from power-producing dams. As with any data collection activity, an important component that cannot be overlooked is the quality of the data. Measurement of data quality allows determination of the usefulness and relevance of the data for current and future decision processes.

This 2008 report:

- Describes the data collection methods.
- Evaluates quality assurance/ quality control (QA/QC) data for the FMS stations at McNary, Ice Harbor, Lower Monumental, Little Goose, and Lower Granite reservoirs. Additionally, this data-collection system provided water-quality information for the Clearwater River downstream of Dworshak Dam, the Columbia River near Pasco, and the Snake River near Anatone, Washington (Figure J-1; Table J-1).

- The QA/QC data includes:
    1. Instrument Data. This data was used to evaluate how an instrument performed as a function of the magnitude and direction that individual sensors deviated over time from their respective laboratory standards. These relationships were determined for each sensor before and after each deployment.
    2. Station Data: These data present comparisons between an in-place instrument that was deployed at a given station for a specified cycle and a newly calibrated QA/QC instrument (field standard). The Sutron® barometers at each station were evaluated with a hand-held barometer that served as a portable field standard for barometric pressure. Fifteen stations were visited for routine maintenance once every three weeks between 1 April and 31 August. The six year-round stations were maintained once every four weeks for the remainder of the year.

3.0 METHODS

3.1 DATA COLLECTION

The instrumentation at each FMS station consisted of components provided by CENWW and the U.S. Geological Survey (USGS) Pasco, Washington, office. A 12-volt battery charged by a solar panel and/or 120-volt alternating-current line powered each station. Thirty-nine Hydrolab® multi-parameter probes (*i.e.*, Minisondes, Minisonde 4A's, and MS5's) were utilized. Thirty-three of these units were provided by CENWW and the remaining six belonged to the USGS. The ten remaining CENWW analog Honeywell® PPT16 electronic barometers that have been used at the stations for several years were phased out at the beginning the 2008 water year and replaced with Sutron Accubar model 5600-0120 barometric pressure sensors.

3.2 LABORATORY PROCEDURES

The TDG sensor measures the sum of the partial pressures of gaseous compounds dissolved in the water and reports the result in millimeters of mercury (mmHg). The TDG sensor requires a two-step calibration procedure (*i.e.*, adjustments are made at two points on the calibration curve) that is completed prior to and after deployment. The atmospheric pressure calibration point (Lab BP) is equal to the atmospheric pressure at the time of calibration as measured with a ParoScientific® digiquartz barometric pressure standard that is calibrated yearly at the factory. The differences between Lab BP and the pressure measured by the sonde [Δ(BP-PT)] were recorded before and after deployment. The slope of each sensor response was also evaluated to ensure that measurements were interpolated correctly over the full range of expected field values. To accomplish this task, a Heise™ PTE-1 hand held certified pressure calibrator, calibrated yearly at the factory (primary standard) and an Ashcroft digital test gauge, also calibrated yearly at the factory (primary standard), were used to apply pressure to the TDG sensor. Three hundred mmHg were added to Lab BP during the pre-deployment check and the differences between Lab BP+300 and the sondes' response were recorded as Δ[(BP+300)-PT]. Similar tests were completed post-deployment when 100 mmHg was added to Lab BP, and the resulting differences were recorded as Δ[(BP+100)-PT]. Pre-deployment pressure tests were made without a membrane installed. Post-deployment tests were made with a dry membrane in place.

Each sonde also includes a sensor for reporting water temperature in degrees Celsius (°C). Sonde thermometers are factory calibrated and cannot be adjusted. However, temperature sensor

performance was evaluated pre- and post-deployment by comparing instrument readings to two Barnant model 600 digital thermistors. Both of these instruments were checked quarterly against a National Institute of Standards and Technology (NIST) mercury thermometer standard.

3.3 FIELD PROCEDURES

The differences in barometric pressure, water temperature, and TDG between a secondary standard instrument (*i.e.,* replacement sonde) and the fixed-station monitors after three or four weeks of field deployment were measured and recorded as part of the field inspection and calibration procedure. These differences, defined as the secondary standard value minus the field instrument value, were used to compare and quantify the precision between two independent instruments. The Sutron® barometers were checked using a Novalynx model 230-355 hand-held digital barometer that is calibrated yearly at the factory. The water temperature and TDG comparisons were made *in situ* with the secondary standard (*i.e.*, a recently calibrated Hydrolab®) positioned alongside the field Hydrolab®.

3.4 DEFINING INVALID AND MISSING DATA VALUES

The real-time data were examined daily during the workweek by CENWW and/or USGS employees. Missing values and those that appeared to be outside the expected range were flagged. If a reasonable explanation (*e.g.*, routine maintenance, DCP failure, or defective membrane) could be attributed to the incident, then the data point, or points, was not included in the final data set used for this analysis. Outlying data points that could not be attributed to a specific cause were retained.

4.0 RESULTS AND DISCUSSION

4.1 INVENTORY-WIDE SONDE QA/QC PERFORMANCE

4.1.1 Pre-deployment

The pre-deployment evaluation of the sondes consisted of 179 individual checks for barometric pressure (Table J-2). The evaluation of the sonde pressure sensors to the standard revealed a calculated mean of 0.15 mmHg, and a range of -1.20 to 1.40 mmHg (Table J-2; Figure J-3). Two hundred millimeters of mercury (mmHg) was added to the TDG sensor in the laboratory using the laboratory barometer as the baseline standard. The difference between the barometer with 300 mmHg of pressure and the instrument was compared against the expected value. The calculated mean was based on the 179 measurements. The sonde pressure differences ranged from -0.1 percent to 0.2 percent (Figure J-4; Tables J-2 and J-3). The calculated mean and median values were both 0.02 percent (Figure J-4; Tables J-2 and J-3).

The dissimilarities between the NIST-traceable thermometer and the sonde thermistors were also quite small. The calculated average and median values for all the instruments were only 0.00 °C and 0.01 °C, respectively. These calculated values were based on 179 measurements, with the medians for individual sonde ranging from –0.27 °C to 0.15 °C (Table J-3; Figure J-5). The instrument manufacturer's specification is ±0.2 °C for all instruments within a sample pool.

4.1.2 Post-deployment

The evaluation of the post-deployment QA/QC data also displayed favorable results. A total of 183 data points were used for the evaluation. The differences between the laboratory barometric pressure and that recorded by the sondes ranged from, -2.00 mmHg to 1.80 mmHg, with a mean of 0.19 mmHg (Tables J-2 and J-4; Figure J-3). The results of the post calibration checks using barometric pressure +100 mmHg showed a calculated mean of 0.00 percent, and a range of -0.2 to 0.2 percent (Table J-2; Figure J-4).

There were 183 post deployment checks available for temperature evaluation. Temperature post calibration checks resulted in a range of -0.25 °C to 0.13 °C (Tables J-2 and J-4; Figure J-5).

4.2 System-wide Station QA/QC Performance

The analysis of the station QA/QC data showed that the in-place barometric air pressure, TDG, and temperature instruments performed well when compared to the secondary standards (Figures J-6 through J-8). A total of 190 readings were used to calculate the mean and median values for barometric pressure (Table J-5). The median of all the differences calculated between the station barometers and the secondary standards was 0.00 mmHg (Table J-5; Figure J-6). The stations where individual values departed from this median to the greatest extent were Dworshak (DWQI) and McNary forebay (MCNA) where the calculated median values were both 0.2 mmHg (Table J-6).

The overall median for the TDG differences between the in-place and replacement sondes was 0.00 percent saturation (Table J-5; Figure J-7). Individual median station values typically ranged from -0.3 percent saturation to 0.2 percent saturation (Table J-6).

A total of 176 readings were used to calculate the temperature mean and median values (Table J-5). The calculated mean and median temperature differentials for the field data were -0.03 °C and -0.02 °C, respectively (Table J-5; Figure J-8). The stations where individual values departed from this median to the greatest extent were Pasco (PAQW) at -0.18 °C and Lower Monumental tailwater (LMNW) at -0.07 °C (Table J-6). The manufacturer's specification for the temperature sensor is +/- 0.20 °C.

4.3 FMS Data Completeness and Station Statistics

Percent completeness for all station/parameters averaged 99.77 percent – exceeding the required 95 percent criterion (Tables J-7 and J-8). The means for the individual TDG, barometric pressure, and temperature parameters were 99.56, 99.85, and 99.90, respectively. The most common reasons for missing or anomalous data were defective membranes (221 hours) and DCP failures (104 hours) (Table J-8). Three additional causes of missing or non-representative data were losses during routine maintenance (39 hours), bad communication cables (38 hours), and unknown spikes (37 hours).

4.3.1 Barometric Pressure

Barometric pressure data was 100 percent complete at nine of the fifteen FMS stations (Table J-7), while five of the remaining stations were greater than 99 percent complete. The station with the lowest percentage was Lower Granite forebay (LWG) at 98.73 percent. Faulty cable connections were the primary reason for the missing data at LWG (Tables J-8 and J-9).

4.3.2 Total Dissolved Gas

The TDG data from the fifteen stations averaged 99.56 percent complete (Table J-7). The McNary forebay (MCNA), Pasco (PAQW), Lower Monumental forebay (LMNA), and Lewiston (LEWI) stations were 100 percent complete. Eight of the remaining stations were greater than 99 percent complete (Table J-7). Defective membranes at the Lower Monumental tailwater, Peck, McNary tailwater, Lower Granite tailwater, and Ice Harbor tailwater stations accounted for the majority of the data losses at those stations, but the calculated completeness were still 98.69, 98.34, 99.66, 99.66, and 98.81 percent, respectively (Table J-7 and J-10). The field crew hypothesized that the presence of immature crayfish that were often found on the membranes were a primary reason for the failed membranes.

4.3.3 Temperature

The temperature data from the fifteen FMS stations averaged 99.9 percent complete. Seven of the stations attained 100 percent completeness (Table J-7) and the remaining eight were all greater than 99 percent complete. The Ice Harbor forebay station had the greatest data loss as a result of DCP failure, but was still 99.18 percent complete (Tables J-7 and J-11).

4.4 Lower Granite Tailwater Station

Log debris in the river during the spring freshet damaged the Lower Granite tailwater station. The mid-May debris field pulled the deployment tube from the "coffin" box on shore and broke some of the mooring cables. The site was temporarily repaired by USGS and USACE personnel. A permanent repair will be completed during the fall/winter low-flow period, but prior to the start of the fish spill season on 1 April 2009.

5.0 SUMMARY

Hourly TDG, temperature, and barometric data recorded during the 2008 water year at fifteen FMS stations were evaluated. Six tailwater sites were maintained throughout the year and nine were monitored from 1 April through 31 August.

The USGS Pasco field office was contracted to perform routine station maintenance, complete emergency repairs, and operate the DCPs. Their pre-deployment QA/QC checks showed an average difference of 0.15 mmHg when the TDG sensor was compared to barometric pressure and 0.02 percent when 300 mmHg of pressure was added. The post-deployment evaluations had mean differences of -0.19 mmHg and 0.00 percent when the TDG sensor was compared to barometric pressure and barometric pressure plus 100 mmHg, respectively. The calculated mean temperature difference was 0.00 °C for pre-deployment and -0.02 °C for post-calibration.

The 39 instruments used to perform this years monitoring met the manufacturers' specifications. Field checks during routine maintenance demonstrated that the air barometric pressure, percent TDG, and temperature averaged 0.00 mmHg, 0.00 percent, and -0.02 °C, respectively, when compared to the secondary standards.

The preventative maintenance schedule provided for calibration and routine maintenance at three week intervals during the fish spill season and once every four weeks during the rest of the year. Station performance was hampered primarily by defective membranes and faulty DCPs.

Defective communications cables, data spikes, and routine maintenance were secondary causes for data losses.

FIGURES

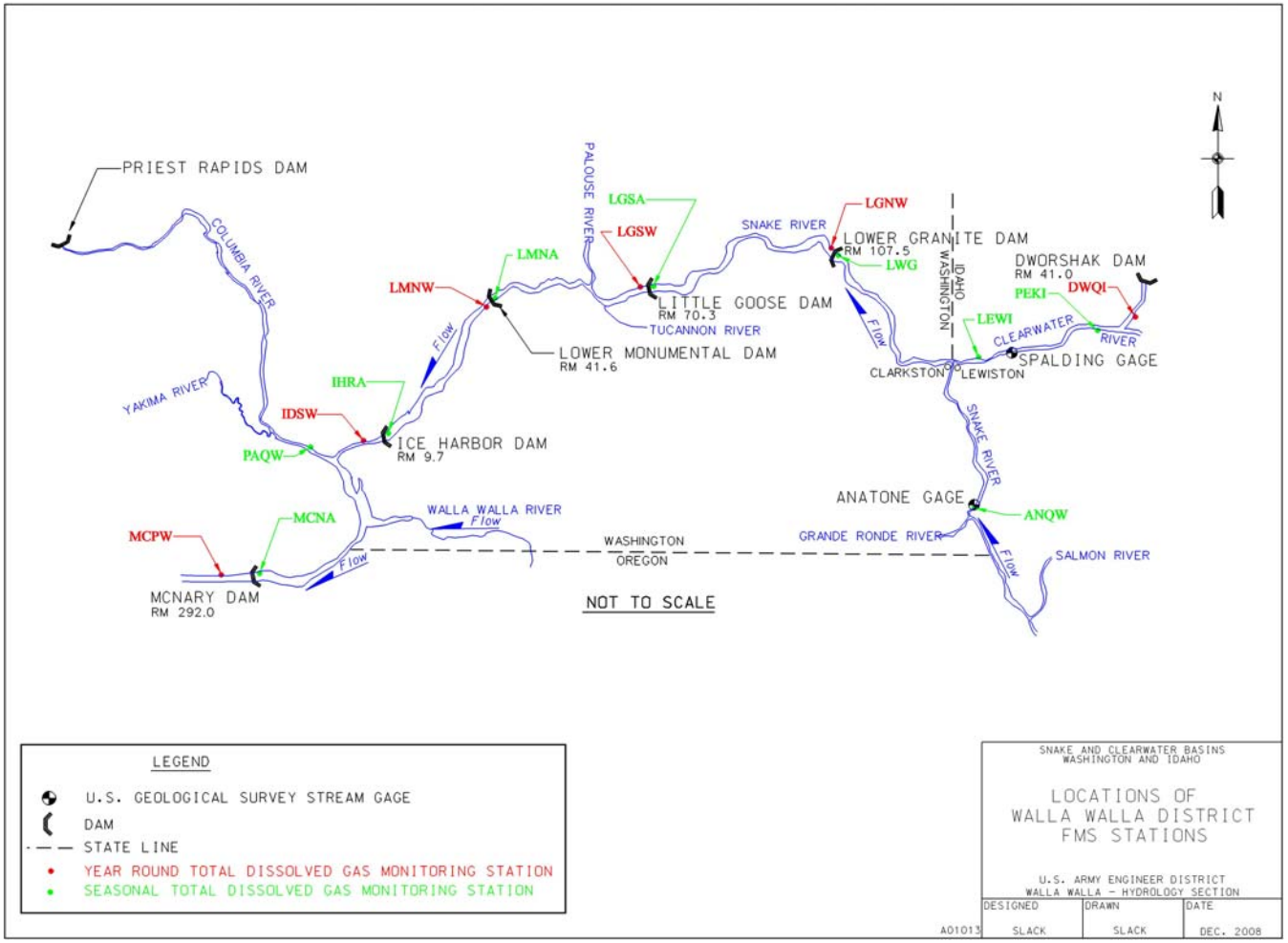

Figure J-1. Locations of Walla Walla District's FMS stations.

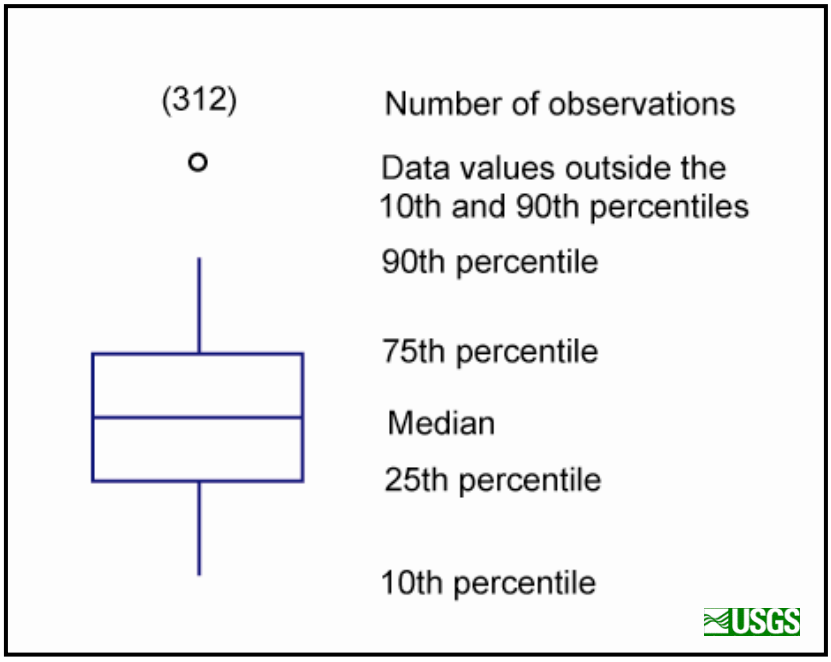

Figure J-2. Explanation key for the box plot information.

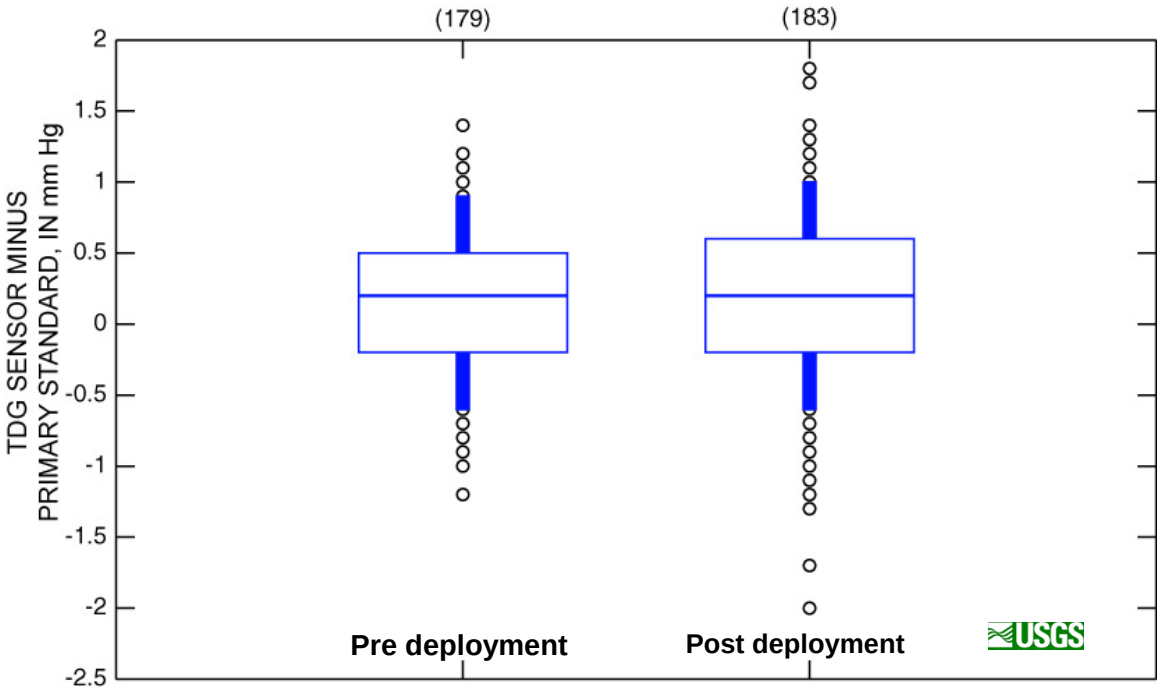

Figure J-3. Summary box plots of the pre-and post-deployment check of the barometric pressure versus the primary standard during the 2008 monitoring season.

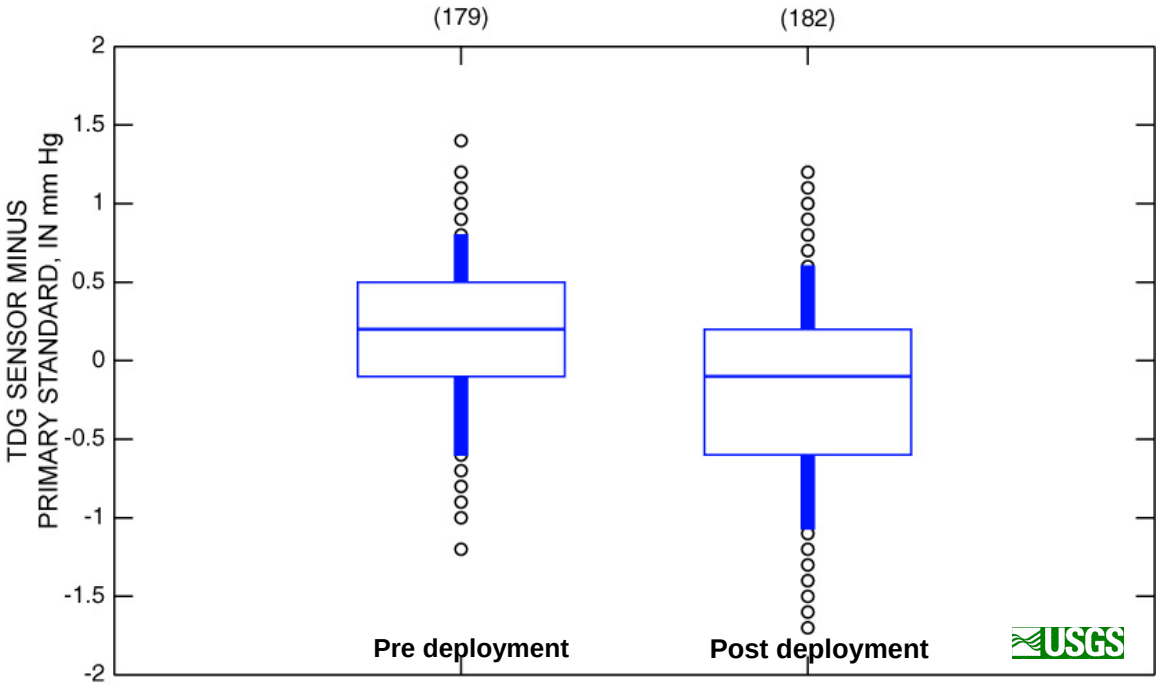

Figure J-4. Summary box plots of the pre-and post-deployment check of the Hydrolab® TDG sensors with the addition of 100 and 300 psi during the 2008 monitoring season.

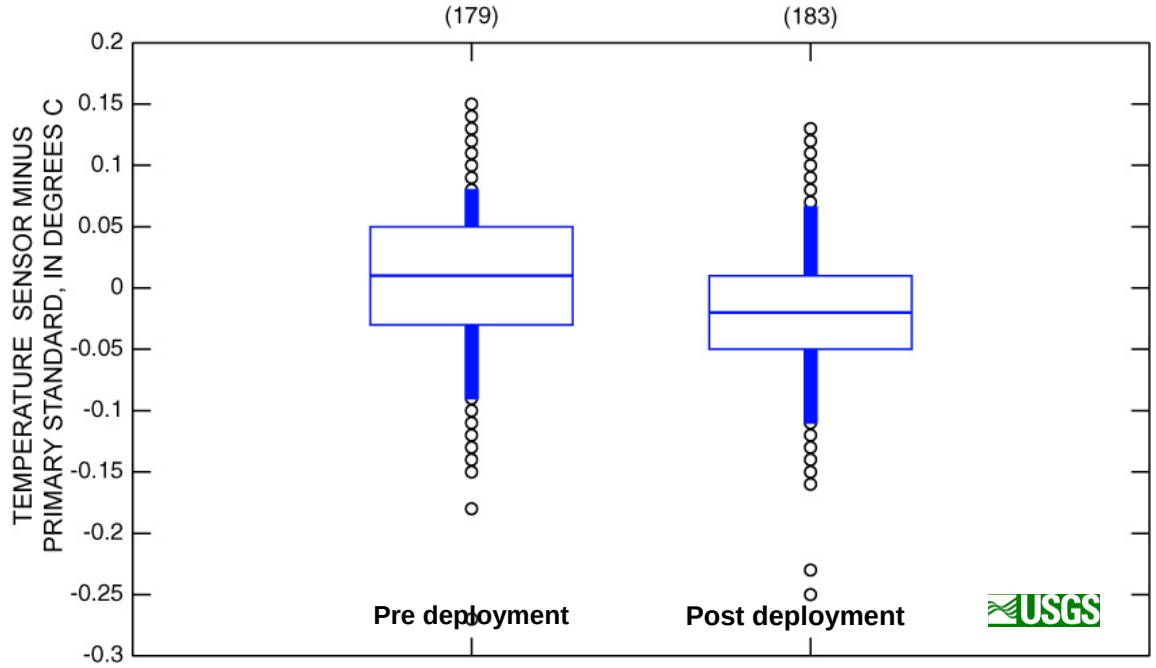

Figure J-5. Summary box plots of the pre- and post-deployment check of the Hydrolab® temperature sensors during the 2008 monitoring season.

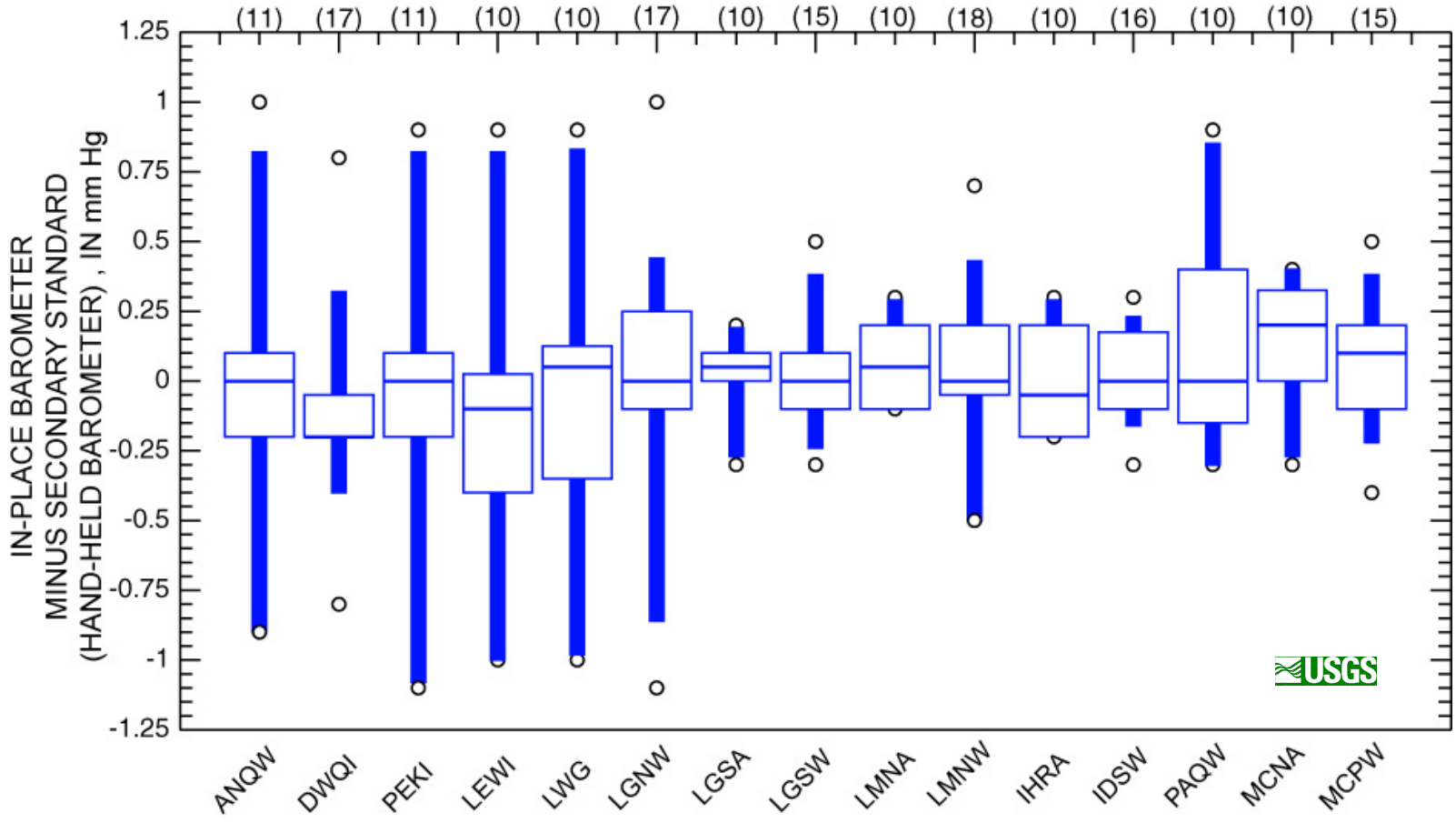

Figure J-6. Box plots of the field barometric pressure check in mm Hg by site during the 2008 monitoring season.

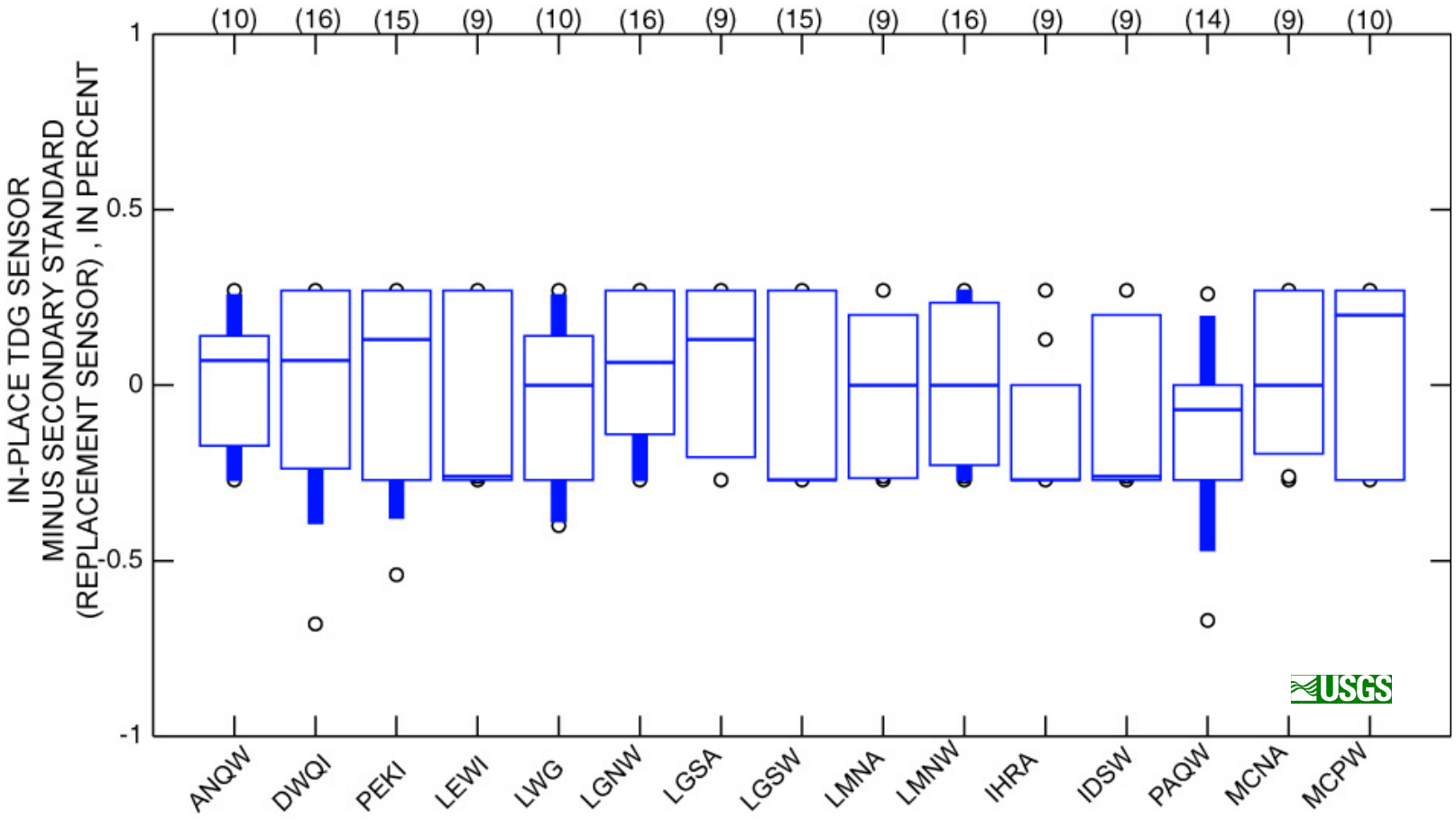

Figure J-7. Box plots of the field total dissolved gas sensor check verses secondary standard in percent saturation by site during the 2008 monitoring season.

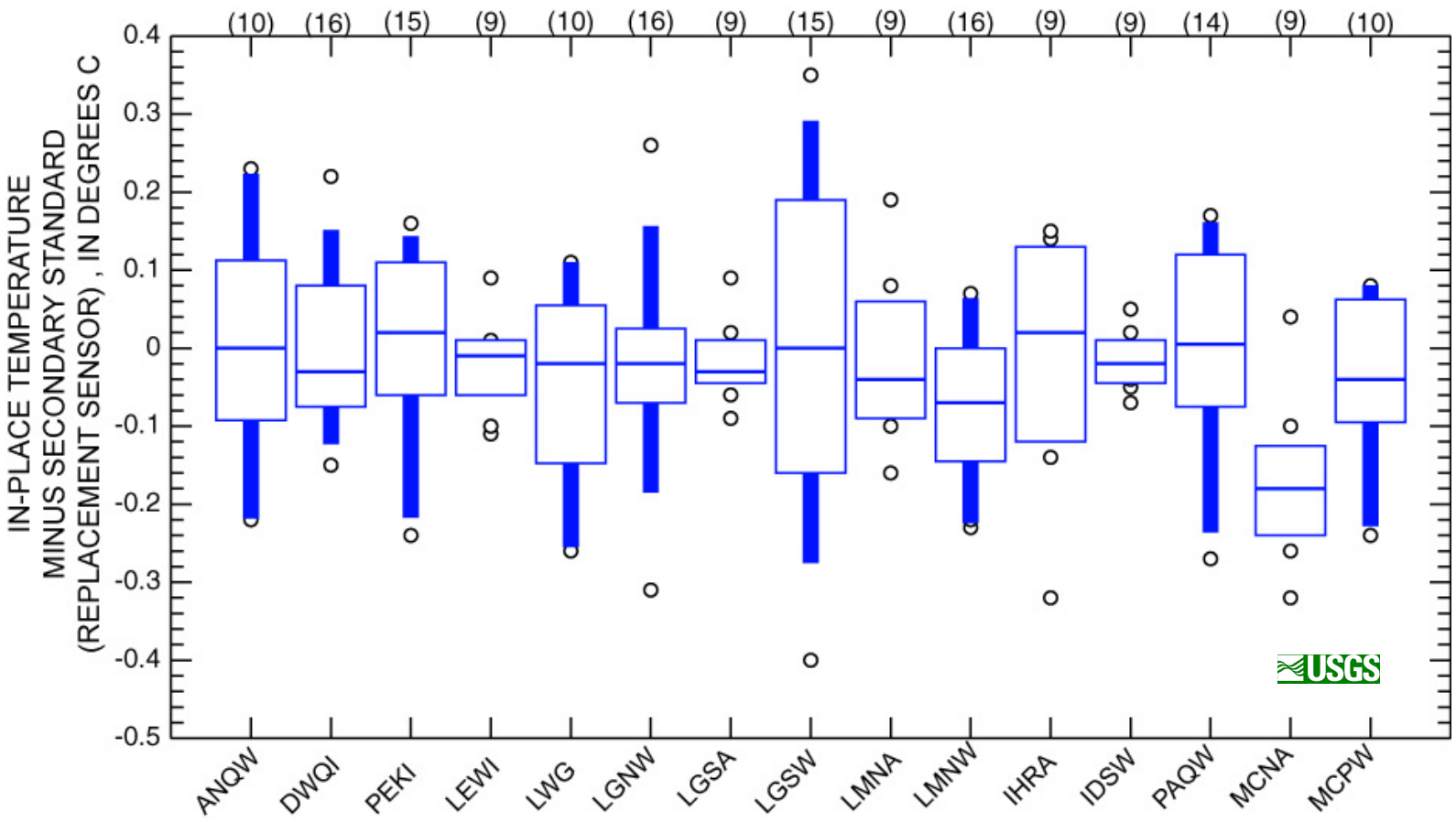

Figure J-8. Box plots of the field temperature sensor check verses secondary standard in degrees C by site during the 2008 monitoring season.

TABLES

Table J-1. CENWW FMS station identification and location information.

Station Number	Station Name	Station ID	Latitude (NAD 83)	Longitude (NAD 83)	Elevation (NGVD 29)	River Mile	DCP ID	XMIT Time
12514400	Columbia River at Pasco, WA	PAQW	46 13 26.2851 N	119 06 57.3388 W	345	329.1	17D6E32C	0:27:10
13334300	Snake River Near Anatone, WA	ANQW	46 05 50.7579 N	116 58 41.2382 W	807	167.5	17D63544	0:16:10
13341000	N.F. Clearwater River at Dworshak Hatchery, ID	DWQI	46 30 11.6464 N	116 19 16.4090 W	1,150	0.5	17D600DE	0:13:10
13341050	Clearwater River Near Peck, ID	PEKI	46 30 00.9396 N	116 23 32.4163 W	930	37.4	17D613A8	0:14:10
13343000	Clearwater River Near Lewiston, ID	LEWI	46 25 52.0867 N	116 56 43.9589 W	750	5.0	17D62632	0:15:10
13343590	Lower Granite Dam Forebay, WA	LWG	46 39 34.1727 N	117 25 34.8564 W	738	107.5	17D643D4	0:17:10
13343595	Lower Granite Dam Tailwater, WA	LGNW	46 39 58.0726 N	117 26 19.2595 W	645	106.7	17D650A2	0:18:10
13343855	Little Goose Dam Forebay, WA	LGSA	46 34 58.3188 N	118 01 32.9831 W	638	70.3	17D66538	0:19:10
13343860	Little Goose Dam Tailwater, WA	LGSW	46 35 00.5280 N	118 02 37.4186 W	560	69.6	17D6764E	0:20:10
13352595	Lower Monumental Dam Forebay, WA	LMNA	46 33 44.6559 N	118 32 08.3477 W	540	41.6	17D686CA	0:21:10
13352600	Lower Monumental Dam Tailwater, WA	LMNW	46 33 04.5051 N	118 32 58.9500 W	445	40.4	17D695BC	0:22:10
13352950	Ice Harbor Dam Forebay, WA	IHRA	46 15 05.2792 N	118 52 43.0096 W	440	10.0	17D6A026	0:23:10
13353010	Ice Harbor Dam Tailwater, WA	IDSW	46 14 27.5868 N	118 57 13.7130 W	340	6.1	17D6B350	0:24:10
14019220	McNary Dam Forebay, WA	MCNA	45 56 28.4473 N	119 17 39.5990 W	340	292.0	17D6D6B6	0:26:10
14019240	McNary Dam Tailwater, WA	MCPW	45 56 02.7775 N	119 19 35.4628 W	240	290.7	17D5F754	0:12:10

Table J-2. Summary of the laboratory results evaluating the overall differences between laboratory standards and the sondes pre- and post deployment during the 2008 water year.

Deployment	Statistic	Δ (BP) (mm Hg)	Δ [(BP+300)-PT] (%)	Δ [(BP+100)-PT] (%)	Δ T (°C)
Pre	Number	179	179	----	179
	Minimum	-1.20	-0.1	----	-0.27
	25 percentile	-0.12	-0.02	----	-0.03
	Median	0.20	0.02	----	0.01
	75 percentile	0.50	0.06	----	0.05
	Maximum	1.40	0.2	----	0.15
	Mean	0.15	0.02	----	0.00
Post	Number	183	----	183	183
	Minimum	-2.00	----	-0.2	-0.25
	25 percentile	-0.38	----	-0.04	-0.05
	Median	0.20	----	0.00	-0.02
	75 percentile	0.40	----	0.05	0.01
	Maximum	1.80	----	0.2	0.13
	Mean	0.19	----	0.00	-0.02

Table J-3. Pre-deployment quality assurance data for the individual sondes utilized at the FMS stations during the 2008 water year.

	Δ (BP – PT)			Δ [(BP+300) – PT]			Δ (Water Temperature)		
Sonde ID	# Obs	Range (mm Hg)	Median (mm Hg)	# Obs	Range (mm Hg)	Median (mm Hg)	# Obs	Range (^{o}C)	Median (^{o}C)
1	7	-0.8 to 1.2	-0.1	7	-0.8 to 1.2	-0.1	7	0.06 to 0.14	0.12
3	6	-0.8 to 0.7	-0.2	6	-1.2 to 0.7	-0.4	6	-0.18 to 0.09	0.05
4	0	-	-	0	-	-	0	-	-
5	5	-0.1 to 0.6	0.3	5	-0.1 to 0.6	0.3	5	-0.04 to 0.02	-0.02
6	4	-0.2 to 0.4	0.3	4	-0.2 to 1.2	0.4	4	-0.06 to -0.03	-0.04
7	2	0.3 to 1.0	0.6	2	0.0 to 0.3	0.1	2	-0.05 to 0.00	-0.03
8	5	-0.1 to 1.0	0.4	5	-0.1 to 0.5	0.3	5	-0.13 to 0.15	-0.13
10	0	-	-	0	-	-	0	-	-
11	5	0.4 to 1.4	1.0	5	0.4 to 1.4	1.0	5	-0.15 to -0.06	-0.13
12	0	-	-	0	-	-	0	-	-
13	4	0.2 to 1.0	0.5	4	0.0 to 0.8	0.2	4	0.08 to 0.10	0.09
14	5	-0.1 to 0.8	0.5	5	-0.1 to 0.8	0.5	5	-0.09 to -0.05	-0.08
15	0	-	-	0	-	-	0	-	-
16	6	-0.9 to 0.4	-0.4	6	-0.9 to 0.4	0.2	6	-0.27 to 0.03	0.01
17	5	0.0 to 0.4	0.1	5	0.0 to 0.4	0.1	5	-0.08 to 0.01	-0.01
18	4	0.3 to 1.0	0.4	4	0.3 to 1.0	0.4	7	-0.11 to -0.07	-0.09
20	0	-	-	0	-	-	0	-	-
21	0	-	-	0	-	-	0	-	-
23	6	0.0 to 0.9	0.3	6	-1.0 to 0.9	0.3	6	-0.02 to 02	0.02
25	5	-1.0 to 0.7	-0.6	5	-0.1 to 0.7	-0.6	5	0.06 to 0.9	0.08
26	1	-0.1 to -0.1	-0.1	1	-0.1 to -0.1	-0.1	1	-0.07 to -0.07	-0.07
27	5	-0.1 to 0.4	0.1	5	-0.1 to 0.4	0.1	5	-0.04 to -0.02	-0.02
28	5	-0.7 to -0.2	-0.5	5	-0.5 to 0.3	-0.4	5	0.02 to 0.08	0.03
29	6	-0.3 to 1.1	0.5	6	-0.3 to 1.1	0.5	6	-0.05 to 0.01	0.01
30	4	-0.1 to 0.1	-0.1	4	-0.1 to 0.1	-0.1	4	-0.12 to 0.09	-0.10
31	6	0.0 to 1.4	0.5	6	0.0 to 1.4	0.5	6	-0.02 to 0.00	-0.01
32	4	-0.6 to 0.1	0.0	4	-0.6 to 0.7	0.0	4	-0.13 to 0.11	-0.02
33	5	-1.21 to 0.3	-0.6	5	-0.6 to 0.3	-0.1	5	-0.09 to 0.02	-0.02
34	4	-0.13 to 1.1	0.3	4	-0.1 to 1.1	0.3	4	-0.05 to 0.05	0.01
35	5	0.0 to 0.7	0.2	5	0.0 to 0.7	0.2	5	0.02 to 0.11	0.05
37	6	-0.9 to 0.9	-0.3	6	-0.8 to 0.9	0.1	6	0.02 to 0.09	0.04
39	5	0.0 to 0.7	0.2	5	-1.0 to 0.7	0.2	5	-0.01 to 0.06	0.01
40	8	-0.6 to 0.2	-0.4	8	-0.6 to 0.2	-0.4	8	-0.05 to 0.06	0.02
41	6	0.0 to 0.8	0.6	6	0.0 to 0.8	0.6	6	-0.07 to 0.06	0.02
50	1	0.3 to 0.3	0.3	1	0.3 to 0.3	0.3	1	0.13 to 0.13	0.13
USGS 1	5	0.0 to 1.2	0.7	5	0.0 to 1.2	0.7	5	0.01 to 0.06	0.04
USGS 2	7	-0.7 to 0.5	-0.3	7	-0.3 to 0.5	0.2	7	-0.14 to 0.05	-0.02
USGS 3	5	-1.0 to 0.3	-0.1	5	-1.0 to 0.3	-0.1	5	0.01 to 0.06	0.05
USGS 4	7	-0.8 to 0.5	-0.1	7	-0.8 to 0.5	-0.1	7	-0.01 to 0.10	0.02
USGS 5	6	-0.5 to 0.8	0.1	6	-0.5 to 0.8	0.1	6	0.00 to 0.05	0.01
USGS 6	6	-0.2 to 0.4	0.3	6	-0.2 to 0.4	0.3	6	-0.06 to 0.06	0.02

Table J-4. Post-deployment quality assurance data for the individual sondes utilized at the FMS stations during the 2008 water year.

	Δ (BP – PT)			Δ [(BP+100) – PT]			Δ (Water Temperature)		
Sonde ID	# Obs	Range (mm Hg)	Median (mm Hg)	# Obs	Range (mm Hg)	Median (mm Hg)	# Obs	Range (^{o}C)	Median (^{o}C)
1	6	-1.0 to 1.7	0.3	6	-1.0 to 0.7	-0.3	6	0.10 to 0.13	0.11
3	6	-1.7 to 0.6	-0.2	6	-1.7 to 0.0	-1.2	6	0.00 to -0.02	0.01
4	0	-	-	0	-	-	0	-	-
5	5	0.0 to 1.4	0.7	5	-1.0 to 0.4	0.2.	5	-0.06 to -0.03	-0.04
6	4	-0.7 to 0.0	-0.1	4	-0.7 to 0.0	-0.1	4	-0.04 to -0.03	-0.04
7	3	0.0 to 0.6	0.4	3	-0.6 to 0.6	0.0	3	-0.09 to 0.00	-0.09
8	6	-1.0 to 0.8	0.6	6	-1.0 to 0.7	-0.3	6	-0.16 to -0.13	-0.15
10	0	-	-	0	-	-	0	-	-
11	4	1.1 to 1.4	1.2	4	0.1 to 1.1	0.3	4	-0.13 to -0.12	-0.13
12	0	-	-	0	-	-	0	-	-
13	5	0.0 to 0.6	0.4	5	-1.0 to 0.4	-0.4	5	0.06 to 0.09	0.07
14	6	0.0 to 1.0	0.6	6	-0.4 to 0.8	0.3	6	-0.10 to -0.07	-0.08
15	0	-	-	0	-	-	0	-	-
16	5	-1.2 to 0.0	-0.2	5	-1.3 to 0.0	-0.2	5	-0.25 to 0.00	0.00
17	6	-0.5 to 1.0	0.1	6	-1.5 to 0.2	0.0	6	-0.13 to -0.02	-0.05
18	6	0.0 to 0.5	0.2	6	-0.5 to 0.3	0.1	6	-0.14 to 0.00	-0.11
20	0	-	-	0	-	-	0	-	-
21	1	-1.2 to -1.2	-1.2	1	-1.2 to -1.2	-1.2	1	-0.23 to -0.23	-0.23
23	6	-0.5 to 1.2	0.4	6	-1.1 to 0.3	-0.4	6	-0.09 to 0.00	-0.02
25	3	-0.5 to 0.8	-0.1	3	-1.5 to 0.9	-0.2	3	0.06 to -0.08	0.07
26	0	-	-	0	-	-	0	-	-
27	5	-0.1 to 1.3	0.7	5	-1.1 to 0.7	0.0	5	-0.08 to -0.03	-0.04
28	4	-1.3 to -0.5	-0.7	4	-0.7 to -0.3	-0.6	4	-0.01 to 0.08	0.01
29	6	-0.6 to 1.4	0.4	6	-1.6 to 0.6	-0.6	6	-0.04 to 0.00	-0.02
30	5	-0.4 to 0.6	0.2	5	-1.4 to 0.4	-0.4	5	-0.11 to -0.10	-0.11
31	7	-0.1 to 1.8	0.2	7	-1.1 to 1.0	0.2	7	-0.08 to 0.00	-0.02
32	4	0.0 to 0.6	0.3	4	0.0 to 0.6	0.3	4	-0.08 to -0.05	-0.07
33	5	-1.0 to 0.9	0.0	5	-1.0 to 0.1	0.0	5	-0.04 to 0.04	-0.02
34	5	-1.0 to 1.7	0.5	5	-1.2 to 0.7	0.0	5	-0.05 to 0.01	-0.02
35	7	-0.8 to 0.9	0.1	7	-0.8 to 0.6	0.0	7	-0.07 to 0.06	0.02
37	6	-0.9 to 0.5	-0.1	6	-0.9 to 0.5	-0.1	6	-0.01 to 0.04	0.01
39	5	0.0 to 0.5	0.1	5	-1.0 to 0.5	0.0	5	-0.05 to 0.01	0.00
40	7	-2.0 to 0.6	0.4	7	-1.0 to 0.4	-0.6	7	-0.07 to 0.06	0.00
41	7	-0.6 to 1.2	1.0	7	-0.1 to 1.2	0.4	7	-0.10 to 0.03	-0.01
50	0	-	-	0	-	-	0	-	-
USGS 1	6	-0.2 to 1.1	0.3	6	-0.6 to 1.1	0.0	6	-0.02 to 0.02	-0.01
USGS 2	5	-1.1 to 0.4	-0.3	5	-1.3 to 0.4	-0.6	5	-0.10 to 0.01	-0.06
USGS 3	6	-1.1 to 0.4	-0.4	6	-1.6 to -0.4	-0.7	6	-0.04 to 0.06	0.03
USGS 4	7	-0.5 to 0.8	0.1	7	-0.3 to 0.8	0.1	7	-0.03 to 0.12	0.07
USGS 5	7	-0.6 to 1.0	-0.1	7	-0.6 to 0.3	-0.2	7	-0.04 to 0.03	0.00
USGS 6	6	0.0 to 0.7	0.6	6	-0.9 to 0.6	-0.1	6	-0.07 to 0.09	-0.04

Table J-5. Summary of the field results for the differences between the in-place and replacement sondes during 2008 water year.

Statistic	Δ BP[1] (mm Hg)	ΔTDG[2] (% sat)	Δ T[2] (^{o}C)
Number	190	176	176
Minimum	-1.10	-0.70	-0.40
Maximum	1.00	0.30	0.35
Mean	0.01	0.00	-0.03
Median	0.00	0.00	-0.02

Footnotes:

[1] Field – laboratory sonde

[2] Replacement – In-place sonde

Table J-6. Summary of the field results for the differences between the in-place and replacement sondes by station during 2008 water year.

	Δ Barometric Air Pressure			Δ Total Dissolved Gas					Δ Water Temperature		
Station ID	# Obs	Range (mm Hg)	Median (mm Hg)	# Obs	Range (mm Hg)	Median (mm Hg)	Range (% Sat)	Median (% Sat)	# Obs	Range (^{o}C)	Median (^{o}C)
MCPW	15	-0.4 to 0.5	0.1	14	-5 to 2	-1	-0.7 to 0.3	-0.1	14	-0.27 to 0.17	0.01
MCNA	10	-0.3 to 0.4	0.2	9	-2 to 2	-2	-0.3 to 0.3	-0.3	9	-0.07 to 0.05	-0.02
PAQW	10	-0.3 to 0.9	0.0	9	-2 to 2	0	-0.3 to 0.3	0.0	9	-0.32 to 0.04	-0.18
IDSW	16	-0.3 to 0.3	0.0	15	-4 to 2	1	-0.5 to 0.3	0.1	15	-0.24 to 0.16	0.02
IHRA	10	-0.2 to 0.3	-0.1	9	-2 to 2	-2	-0.3 to 0.3	-0.3	9	-0.11 to 0.09	-0.01
LMNW	18	-0.5 to 0.7	0.0	16	-2 to 2	0	-0.3 to 0.3	0.0	16	-0.23 to 0.07	-0.07
LMNA	10	-0.1 to 0.3	0.0	9	-2 to 2	0	-0.3 to 0.3	0.0	9	-0.16 to 0.19	-0.04
LGSW	15	-0.3 to 0.5	0.0	15	-2 to 2	-2	-0.3 to 0.3	-0.3	15	-0.40 to 0.35	0.00
LGSA	10	-0.3 to 0.2	0.0	9	-2 to 2	1	-0.3 to 0.3	0.1	9	-0.09 to 0.09	-0.03
LGNW	17	-1.1 to 1.0	0.0	16	-2 to 2	1	-0.3 to 0.3	0.1	16	-0.31 to 0.26	-0.02
LWG	10	-1.0 to 0.9	0.1	9	-2 to 2	-2	-0.3 to 0.3	-0.3	9	-0.32 to 0.15	0.02
ANQW	11	-0.9 to 1.0	0.0	10	-2 to 2	1	-0.3 to 0.3	0.1	10	-0.22 to 0.23	0.00
LEWI	10	-1.0 to 0.9	-0.1	10	-3 to 2	0	-0.4 to 0.3	0.0	10	-0.26 to 0.11	0.0
PEKI	11	-1.1 to 0.9	0.0	10	-2 to 2	2	-0.3 to 0.3	0.2	10	-0.24 to 0.08	-0.04
DWQI	17	-0.8 to 0.8	-0.2	16	-5 to 2	1	-0.7 to 0.3	0.1	16	-0.15 to 0.22	-0.03

Table J-7. Database completeness with the number and percent of all missing or invalid barometric pressure, total dissolved gas, and temperature points for each FMS station during the 2008 water year

Station ID	Monitoring Period	Barometric Pressure		Total Dissolved Gas		Temperature	
		Number Missing/ Anomalous	% Complete	Number Missing/ Anomalous	% Complete	Number Missing/ Anomalous	% Complete
MCPW	1 Oct – 30 Sep	0	100.00	**30**	**99.66**	**1**	**99.99**
MCNA	1 Apr – 31 Aug	0	100.00	0	100.00	0	100.00
PAQW	1 Apr – 31 Aug	0	100.00	0	100.00	0	100.00
IDSW	1 Oct – 30 Sep	0	100.00	**17**	**99.81**	**3**	**99.97**
IHRA	1 Apr – 31 Aug	**30**	**99.18**	**30**	**99.18**	**30**	**99.18**
LMNW	1 Oct – 30 Sep	0	100.00	**115**	**98.69**	0	100.00
LMNA	1 Apr – 31 Aug	0	100.00	0	100.0	0	100.00
LGSW	1 Oct – 30 Sep	0	100.00	**12**	**99.86**	0	100.00
LGSA	1 Apr – 31 Aug	**1**	**99.97**	**1**	**99.97**	**1**	**99.97**
LGNW	1 Oct – 30 Sep	**1**	**99.99**	**30**	**99.66**	**2**	**99.98**
LWG	1 Apr – 31 Aug	**10**	**98.73**	**12**	**99.67**	**12**	**99.67**
ANQW	1 Apr – 31 Aug	0	100.00	**1**	**99.97**	0	100.00
LEWI	1 Apr – 31 Aug	0	100.00	0	100.00	0	100.00
PEKI	1 Apr – 31 Aug	**2**	**99.95**	**61**	**98.34**	**6**	**99.84**
DWQI	1 Oct – 30 Sep	**3**	**99.97**	**32**	**98.64**	**4**	**99.95**

Table J-8. Summary of the total hours of barometric pressure, total dissolved gas, and temperature data that were missing or considered invalid in the 2008 water-year data set.

	BP		TDG		BP+TDG			Temperature		All	
Reason	hours	%	hours	%	hours	% of hours	% of bad data	hours	%	hours	%
Too low	0		0		0			0		0	
Missed xmit	1	<0.01	1	<0.01	2	<0.01	0.52	1	<0.01	3	<0.01
Missing data	2	<0.01	1	<0.01	3	<0.01	0.77	1	<0.01	4	<0.01
Spike	0		31	0.04	31	0.04	7.99	6	0.01	37	0.04
Inspection	4	<0.01	28	0.03	32	0.04	8.25	7	0.01	39	0.05
Defective membrane	0	<0.01	221	0.26	221	0.26	56.96	0	<0.01	221	0.26
Defective sonde	0		1	<0.01	1	<0.01	0.26	1	<0.01	2	<0.01
DCP failure	30	0.03	44	0.05	74	0.09	19.07	30	0.03	104	0.12
Cable failure	10	0.01	14	0.02	24	0.03	6.19	14	0.02	38	0.04
Totals	**47**	**0.05**	**341**	**0.40**	**388**	**0.45**	**100.00**	**60**	**0.07**	**448**	**0.52**

Table J-9. Number and percent of all missing or invalid barometric pressure data for each FMS station during the 2008 water year, along with the reasons for those designations.

Station ID	Cable Failure		Missed Transmission		Too Low Value		Spike		Routine Maintenance		Defective Membrane		Defective Sonde		DCP Failure		Missing DCP Data	
	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%
MCPW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MCNA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PAQW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
IDSW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
IHRA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	30	0.74	-	-
LMNW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
LMNA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
LGSW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
LGSA	-	-	-	-	-	-	-	-	1	0.02	-	-	-	-	-	-	-	-
LGNW	-	-	-	-	-	-	-	-	1	0.01	-	-	-	-	-	-	-	-
LWG	10	0.25	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ANQW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
LEWI	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PEKI	-	-	-	-	-	-	-	-	2	0.02	-	-	-	-	-	-	1	0.02
DWQI	-	-	1	0.01	-	-	-	-	1	0.01	-	-	-	-	-	-	1	0.01

Table J-10. Number and percent of all missing or invalid total dissolved gas data for each FMS station during the 2008 water year, along with the reasons for those designations.

Station ID	Cable Failure		Missed Transmission		Too Low Value		Spike		Routine Maintenance		Defective Membrane		Defective Sonde		DCP Failure		Missing DCP Data	
	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%
MCPW	-	-	-	-	-	-	-	-	2	0.02	28	0.32	-	-	-	-	-	
MCNA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PAQW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
IDSW	2	0.02	-	-	-	-	1	0.01	3	0.03	10	0.11	1	0.01	-	-	-	-
IHRA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	30	0.74	-	-
LMNW	-	-	-	-	-	-	1	0.01	1	0.01	113	1.29	-	-	-	-	-	-
LMNA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
LGSW	-	-	-	-	-	-	-	-	12	0.14	-	-	-	-	-	-	-	-
LGSA	-	-	-	-	-	-	-	-	1	0.02	-	-	-	-	-	-	-	-
LGNW	-	-	-	-	-	-	14	0.16	2	0.02	14	0.16	-	-	-	-	-	-
LWG	12	0.30	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ANQW	-	-	-	-	-	-	-	-	1	0.02	-	-	-	-	-	-	-	-
LEWI	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PEKI	-	-	-	-	-	-	4	0.10	1	0.02	56	1.39	-	-	-	-	-	-
DWQI	-	-	1	0.01	-	-	11	0.13	5	0.06	-	-	-	-	14	0.16	1	0.01

Table J-11. Number and percent of all missing or invalid temperature data for each FMS station during the 2008 water year, along with the reasons for those designations.

Station ID	Cable Failure		Missed Transmission		Too Low Value		Spike		Routine Maintenance		Defective Membrane		Defective Sonde		DCP Failure		Missing DCP Data	
	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%
MCPW	-	-	-	-	-	-	1	0.01	-	-	-	-	-	-	-	-	-	
MCNA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PAQW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
IDSW	2	0.02	-	-	-	-	-	-	-	-	-	-	1	0.01	-	-	-	-
IHRA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	30	0.74	-	-
LMNW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
LMNA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
LGSW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
LGSA	-	-	-	-	-	-	-	-	1	0.02	-	-	-	-	-	-	-	-
LGNW	-	-	-	-	-	-	-	-	2	0.02	-	-	-	-	-	-	-	-
LWG	12	0.30	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ANQW	-	-	-	-	-	-	-	-	1	0.02	-	-	-	-	-	-	-	-
LEWI	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PEKI	-	-	-	-	-	-	5	0.12	1	0.02	-	-	-	-	-	-	-	-
DWQI	-	-	1	0.01	-	-	-	-	1	0.01	-	-	-	-	-	-	1	0.01