Appendix G

2023 Portland District TDG Report

U.S. Army Corps of Engineers Portland District Quality-Assurance and Quality-Control Evaluation of the 2022-2023 Total Dissolved Gas and Water Temperature Data in the Lower Columbia River

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Significant Findings

An analysis of total-dissolved-gas (TDG) pressure, barometric pressure, and water-temperature data collected at seven fixed monitoring stations on the lower Columbia River in Oregon and Washington in water year 2023 indicated the following:

- Data received in real-time from the seven individual monitoring sites ranged from 93.9 percent (at Cascade Island) to 100 percent complete (at The Dalles forebay).
- Criteria for real-time data completeness (95 percent) were met at all monitoring stations except Cascade Island (93.9 percent). The telemetered sonde was replaced with an internal logging sonde from May 15-24, 2023, in anticipation of high flow. Excluding that period, data completeness was 99.9 percent at the site.
- After approximately three to four weeks of deployment in the river, 59 of 68 TDG sensor field checks were within approximately ±0.5 percent saturation of a secondary standard sensor. Three field checks that failed this standard were due to ruptured or leaking TDG membranes that resulted in deleted TDG data. Six other comparisons were within ±0.5 to 1.2 percent saturation and no data were deleted as a result of these comparisons.
- One of 68 barometric pressure field checks was greater than ±1 mmHg of a primary standard, ranging from -0.8 to +390.6 mmHg. The difference of +390.6 mmHg was due to a malfunctioning barometer at Warrendale that logged erroneous for five days in late January before it was replaced. The erroneous data could not be corrected and was deleted.
- All 66 water-temperature field checks were within ±0.2 °C of a secondary standard, ranging from -0.09 to + 0.07 °C.
- All 68 TDG sensor laboratory checks that were performed after field deployment were within ±0.3 percent saturation of a primary standard at ambient air pressure and at ambient air pressure plus 300 mmHg.
- During each scheduled site visit, the TDG sensors were field checked, removed and replaced with recently calibrated sensors, and brought to the lab for calibration checks. The three year-round tailwater sites were visited monthly from October 2022 through March 2023. The four seasonal sites were installed April 4-5, 2023. All seven sites were then visited every three to four weeks from early April 2023 through mid-September 2023 (except in early August when personnel were not available).

1.0 Introduction

The U.S. Army Corps of Engineers (USACE) operates several dams in the lower Columbia River Basin in Oregon and Washington (fig. G-1), which encompasses 259,000 mi^2 of the Pacific Northwest. These dams are multipurpose structures that fulfill 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 through the spillways of these dams (instead of being routed through the turbines to generate electricity), ambient air is entrained in the water. This results in an increase in the concentration of dissolved gases (referred to here as "total dissolved gas," or "TDG") in the water downstream of the spillways. The USACE regulates streamflow and spill from its dams on the lower Columbia River to minimize the production of excess TDG downstream of the dams, with the additional goal of providing for fish passage through the spillways.

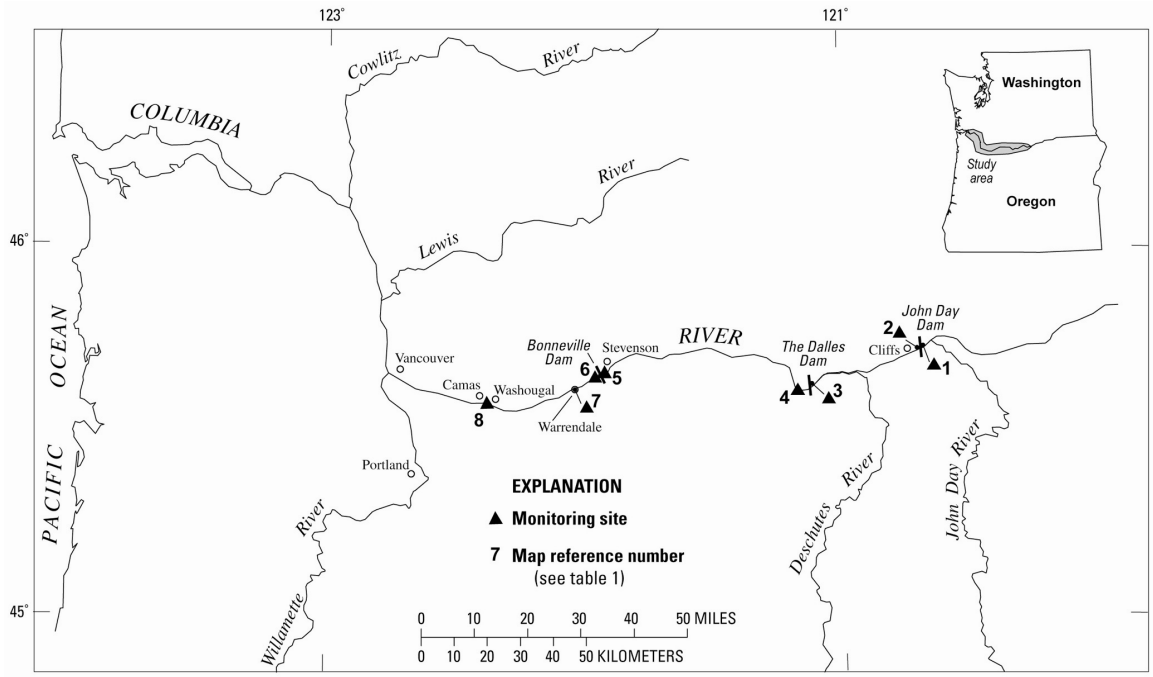

Figure G-1. Location of U.S. Army Corp of Engineers dams and total-dissolved-gas monitoring stations, lower Columbia River, Oregon and Washington, water year 2023.

Real-time TDG, barometric pressure, and water-temperature data are vital to the 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 ensure their survival in the lower Columbia River. The U.S. Geological Survey (USGS), in cooperation with the Portland District of the USACE, has collected TDG and related data in the lower Columbia River each year since 1996. The hourly values are stored in both the USGS database and in a USACE database and are available online within approximately one hour of the time of collection. The current and historical TDG and water-temperature data in the USGS database can be accessed at *https://waterdata.usgs.gov/or/nwis/current/?type=usacetdg&group_key=basin_cd*

(accessed October 31, 2023). The USACE database also includes hourly river discharge and spill data at *http://pweb.crohms.org/ftppub/water_quality/tdg/* (accessed October 31, 2023).

This report presents the TDG, barometric pressure, and water temperature quality-assurance and quality-control data that demonstrate the USACE Portland District compliance with the 2019 TDG monitoring plan. To assure the accuracy and integrity of the data needed for managing and modeling TDG in the lower Columbia River, hourly values were reviewed relative to concurrent field measurements, laboratory sensor calibrations, and inter-site comparisons. All deleted or missing data are explained in detail.

2.0 Data Collection

Seven monitoring stations were operated on the lower Columbia River, from the navigation lock of the John Day Dam (river mile [RM] 215.7) to Dodson, Oregon (RM 140.3) (fig. G-1, table G-1). Data for water year 2023 (October 1, 2022 - September 30, 2023) include hourly measurements of TDG pressure, barometric pressure, water temperature, and sensor depth. The John Day tailwater, The Dalles tailwater, and Warrendale stations are operated year-round. Warrendale is used to provide backup data for Cascade Island during the spill season and assists in monitoring TDG levels in relation to chum redds below Bonneville Dam during the winter. Four seasonal stations were operated from early-April through mid-September 2023, encompassing the usual period for Lower Columbia dam spill operations (April 10 to August 31).

The Warrendale site was moved on August 10, 2023. The dock on which the monitoring site was moved to in 2022 was scheduled for repairs, so the equipment was moved approximately 30 ft upstream on the same dock and will remain in the new location.

Instrumentation at each monitoring station consists of a Hydrolab or Hydrotech water-quality sonde, a Vaisala electronic barometer, and a Sutron SatLink2 or SatLink3 data-collection platform (DCP). The instruments at each station are powered by a 12-volt battery that is charged by a solar panel. Measurements are collected, logged, and transmitted every hour. The DCP transmits the four most recent hours of logged data to the Geostationary Operational Environmental Satellite system (GOES). The data are transferred and automatically decoded to the USACE and USGS databases.

Station visits were completed monthly (every 4-5 weeks) at the three year-round tailwater stations from September 2022 to March 2023. Cascade Island and the three forebay stations were installed April 4-5, 2023. All seven sites were then visited every three to four weeks until September 2023 except during early August (resulting in a six-week interval between visits at most sites). Cascade Island was removed September 1, 2023, to minimize the period of non-representative TDG data observed after spill from Bonneville Dam ends. The three forebay sites were removed September 18-19, 2023.

The field check procedure was as follows: A reference Hydrolab sonde (which was calibrated before the field trip for use as a secondary standard) was deployed alongside the field-deployed instrument and allowed to equilibrate in order to obtain comparison measurements of TDG and water temperature. The field instrument (which had been deployed for 3 or more weeks) was then removed and replaced with another sonde that

had been recently calibrated in the laboratory. After the newly deployed instrument equilibrated, the secondary standard was again used to compare TDG and water temperature values. Any needed adjustment to the water temperature offset was then made within the DCP program. The electronic barometer at the monitoring station was checked against a portable barometer (NovaLynx 230-M202) that is calibrated annually to National Institute of Standards and Technology (NIST) standards. If necessary, the barometric pressure offset was also adjusted.

The sonde that was removed from the field was later checked in the laboratory. The integrity and responsiveness of the TDG membrane was tested, and the membrane was removed and air-dried. The TDG sensor (without the membrane attached) was tested (and recalibrated, if necessary) at a range of pressures spanning the expected range of TDG in the river. The membrane was then installed on the TDG sensor and retested.

Table G-1. Total-dissolved-gas monitoring stations, lower Columbia River, Oregon and Washington, water year 2023.

[Map reference number refers to figure G-1; River mile is distance from the mouth of the Columbia River.]

Map reference number	USACE station identifier	River mile	USGS station number	USGS station name (and abbreviated station name)	Latitude (NAD27)	Longitude (NAD27)	Period of record in water year 2022
1	JDY	215.7	454314120413701	Columbia River at John Day navigation lock, Washington (John Day navigation lock)	45° 43’ 14”	120° 41’ 37”	04/05/23–09/18/23
2	JHAW	214.8	454249120423500	Columbia River, right bank, near Cliffs, Washington (John Day tailwater)	45° 42’ 49”	120° 42’ 35”	10/01/22–09/30/23
3	TDA	192.4	453712121071200	Columbia River at The Dalles Dam forebay, Washington (The Dalles forebay)	45° 37’ 12”	121° 07’ 12”	04/05/23-09/19/23
4	TDDO	189.1	14105700	Columbia River at The Dalles, Oregon (The Dalles tailwater)	45° 36’ 27”	121° 10’ 20”	10/01/22–09/30/23
5	BON	146.1	453845121562000	Columbia River at Bonneville Dam forebay, Washington (Bonneville forebay)	45° 38’ 45”	121° 56’ 20”	04/04/23–09/19/23
6	CCIW	145.9	453845121564001	Columbia River at Cascade Island, Washington (Cascade Island)	45° 38’ 45”	121° 56’ 40”	04/04/23–09/01/23
7	WRNO	140.3	453630122021400	Columbia River, left bank, near Dodson, Oregon (Warrendale)	45° 36’ 30”	122° 02’ 14”	10/01/22–09/30/23

3.0 Data Completeness

To assure the accuracy and integrity of the TDG data in the lower Columbia River, hourly values were reviewed relative to concurrent field measurements, laboratory instrument calibrations, and daily inter-site comparisons. A summary of the completeness of the TDG percent saturation data is shown in table G-2. Data were based on the total number of hourly TDG and barometric pressure data values that could have been collected during the monitoring season. TDG saturation values were considered to meet quality-assurance standards if they were within ±1 percent saturation of the expected value.

Table G-2. Completeness and quality of real-time total-dissolved-gas or barometric pressure data, lower Columbia River, Oregon and Washington, water year 2023.

Abbreviated station name (USACE station identifier)	Planned monitoring (hours)	Number of missing or deleted hourly values	Percent of real-time TDG data passing quality assurance criteria
John Day navigation lock (JDY)	3,988	8	99.8
John Day tailwater (JHAW)	8,760	242	97.2
The Dalles forebay (TDA)	4,005	0	100
The Dalles tailwater (TDDO)	8,760	420	95.2
Bonneville forebay (BON)	4,035	26	99.3
Cascade Island (CCIW)	3,601	218	93.9[1]
Warrendale (WRNO)	8,760	172	98.0

[1]When excluding the period when equipment was removed to prevent high flow damage, completeness is 99.9 percent.

Periods for which substantial amounts of TDG or barometric pressure data were missing from the database are listed in table G-3. Deletions associated with the equilibration of newly deployed sensors during site visits are not included in the table.

Table G-3. Periods of missing or deleted real-time total-dissolved-gas (TDG) or barometric pressure (BP) data, lower Columbia River, Oregon and Washington, water year 2023.

Date(s)	USACE station identifier	Reason / Note
07/06/23 to 09/17/23	JDY	Erroneous TDG values – Sporadic faulty transmissions: Data later recovered
02/17/23 to 02/21/23	JHAW	Missing sonde data (TDG, water temperature, depth) – Faulty instrument cable
08/24/23 to 08/30/23	JHAW	Erroneous TDG values – Membrane slowly leaking
08/06/23 to 08/11/23	TDDO	Erroneous TDG values – Ruptured membrane
08/13/23 to 08/15/23	TDDO	Erroneous TDG values – Ruptured membrane
08/18/23 to 08/28/23	TDDO	Missing sonde data (TDG, water temperature, depth) – Faulty instrument cable
04/04/23 to 04/06/23	BON	Missing sonde data (TDG, water temperature, depth) – Faulty sonde
05/14/23 to 05/15/23	BON	Missing sonde data (TDG, water temperature, depth) – Faulty instrument cable
05/15/23 to 05/24/23	CCIW	Missing sonde data (TDG, water temperature, depth) – Data later recovered from logging sonde
11/02/22 to 11/04/22	WRNO	Missing sonde data (TDG, water temperature, depth) – Faulty instrument cable
12/24/22	WRNO	Missing transmissions – Reason unknown; All data later recovered
01/19/23 to 01/25/23	WRNO	Erroneous BP values – Faulty barometer
08/10/23	WRNO	Missing all data – Site moved to repaired section of dock

During the May 17, 2023, site visit, the sonde deployed at the John Day forebay site was found to be wedged under the guide wall of the navigation channel and could not be retrieved. Field checks of the TDG and water temperature data were within criteria, so the sonde was left in place, at approximately 11 feet depth. In early June, the air temperatures in the area exceeded 90°F and the water temperature at the shallower depth was notably higher than at the John Day tailwater site. During the visit on June 6, a new sonde and cable were deployed at the normal 32 feet depth. Field checks indicate the temperature difference between the two depths was nearly 2°C. No TDG or water temperature data were deleted as a result of the shallower deployment.

TDG data from previous years indicate non-spill factors may affect water circulation at the John Day tailwater deployment pipes and consequently, the TDG measurements. To reduce stagnant conditions or a buildup of sediment in the deployment pipes during the spill season, both the reference and site sonde pipes were flushed with compressed air on April 6 and August 15, 2023. No data were deleted during water year 2023 due to stagnation or sediment accumulation at the site.

Water temperature data were missing at the John Day tailwater site following the replacement of the faulty instrument cable that caused the missing TDG data February 17-21, 2023. The newly

deployed sonde had a faulty temperature sensor that indicated negative values once submerged. The sonde was deployed until March 1, when it was replaced.

The faulty instrument cable at the Bonneville forebay site that caused several missing TDG values in May and June also resulted in more regular missing water temperature data from May 11 to June 26, 2023, when the cable was replaced.

The telemetered sonde was removed from CCIW on May 15, 2023, in anticipation of high flow below Bonneville Dam that could overtop the deployment pipe and damage the equipment. An internal logging sonde was deployed until May 24 and the TDG value was verified by a reference sonde before removal. The TDG and temperature values from the logging sonde were loaded to the database on May 25. The temperature data were corrected by -0.05°C prior to loading based on comparison to the reference sensor temperature during the deployment.

4.0 Quality-Assurance Data

The collection of accurate data for TDG, barometric pressure, and water temperature involves several quality-assurance procedures, including side-by-side instrument comparisons in the field, sensor calibrations in the laboratory, daily checks of the data, and data review and archiving. The results of the quality-assurance procedures for water year 2023 are presented in this section.

After field deployment for 3 or more weeks, the TDG instruments were tested and calibrated in the laboratory. First, the sensor was tested, with the gas-permeable membrane in place, for response to supersaturated conditions in soda water. The membrane was then cleaned, removed from the sensor, and allowed to dry for at least 24 hours. Before replacing the membrane, the TDG sensors were examined independently by comparing the reading of the TDG sensor to barometric pressure (100-percent saturation). Using a certified digital pressure gage (primary standard), comparisons also were made at pressures of 300 mmHg greater than barometric pressure (approximately 139-percent saturation). The accuracy of the TDG sensors was calculated as the difference between the primary standard and the TDG sensor reading (expected minus actual) for the two test conditions divided by the barometric pressure and multiplied by 100 to obtain a percent difference. All 68 TDG sensor laboratory checks performed after field deployment were within ±0.3 percent saturation of a primary standard at both test conditions (fig. G-2).

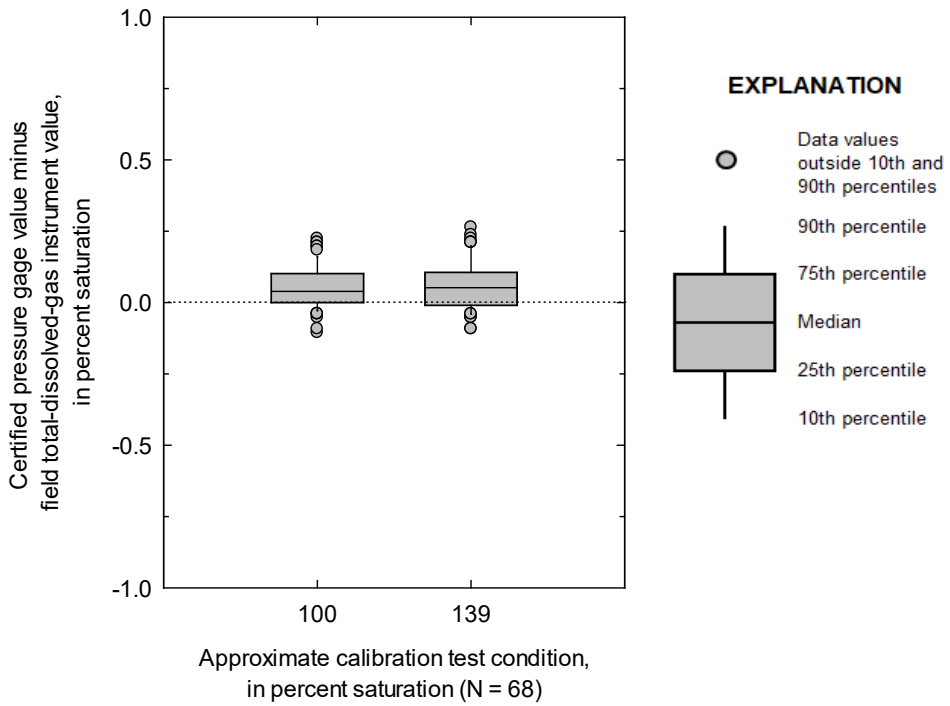

Figure G-2. Accuracy of total-dissolved-gas sensors in the laboratory after 3 or more weeks of field deployment at seven monitoring stations in the lower Columbia River, Oregon and Washington, water year 2023 (number of comparison values = 68).

The differences in barometric pressure, water temperature, and TDG between the reference instruments and the station monitors at the end of their field deployment were measured and recorded as part of every field inspection. These differences, calculated as the standard values minus the field instrument values, were used to compare and quantify the accuracy and precision between the two instruments. For water temperature and TDG, the measurements were made with the secondary standard (a recently calibrated Hydrolab) positioned alongside the monitor deployed in the river. A digital barometer (NIST certified through December 2023) served as the primary standard for barometric pressure. The distribution of quality-assurance data for each of the three parameters from the seven stations is shown in figures G-3, G-4, and G-5. The data used to generate the boxplots in figures G-2–5 are shown in tables G-4 and G-5.

Comparisons of the digital reference barometer and the field barometers are shown in figure G-3. One of the 68 field check values was greater than ±1.0 mm Hg of standard values, ranging from -0.8 mmHg to +390.6 mmHg. The difference of +390.6 mmHg was due to a malfunctioning barometer at Warrendale, and 5 days of data were later deleted. This comparison reading is not included in the distribution analysis (figure G-3) because it does not represent the barometer's accuracy during normal function.

The comparisons of the secondary standard temperature sensor and the field temperature sensors are presented in figure G-4. The differences of all 66 field checks were within ±0.20 °C, ranging from -0.09 to +0.07 °C.

Differences between the secondary standard TDG sensor and the field TDG sensors were computed following equilibration of the secondary standard instrument to site conditions before removing the field instrument. The equilibrium was generally considered complete after a minimum of 20 minutes (and a maximum of 2 hours) when the TDG values for the sensors were within 3-4 mmHg (approximately ±0.5 percent saturation). A total of 68 TDG field checks were done at the seven monitoring sites and nine checks exceeded this guideline. Five of these comparisons were within ±0.5 to 1.1 percent saturation, likely due to incomplete equilibration of the reference sensor, and no data were deleted. The final field check at Cascade Island (before seasonal decommissioning) was +1.2 percent saturation due to the rapidly changing TDG after spill had ended, and no data were deleted. Three checks that exceeded the criteria were due to ruptured or leaking TDG membranes that resulted in deleted data - two at The Dalles tailwater and one at John Day tailwater. These three comparison readings are not included in distribution analysis (fig. G-5). because these data do not represent the TDG sensor's accuracy during normal function.

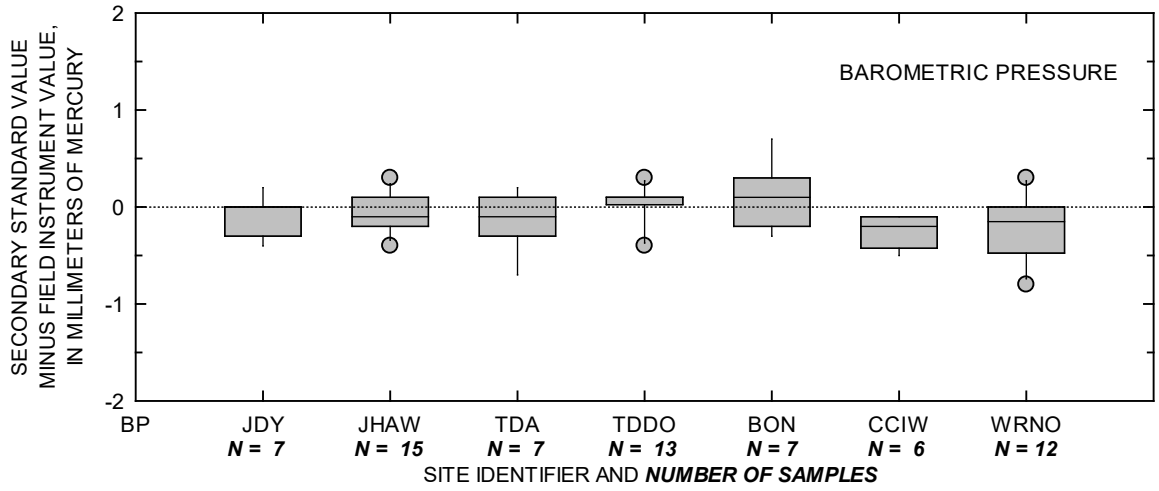

Figure G-3. Difference between the secondary standard and the field barometers in the field after 3 or more weeks of deployment at seven stations in the lower Columbia River, Oregon and Washington, water year 2023. See figure G-2 for explanation of boxplots and table G-1 for definitions of station identifiers.

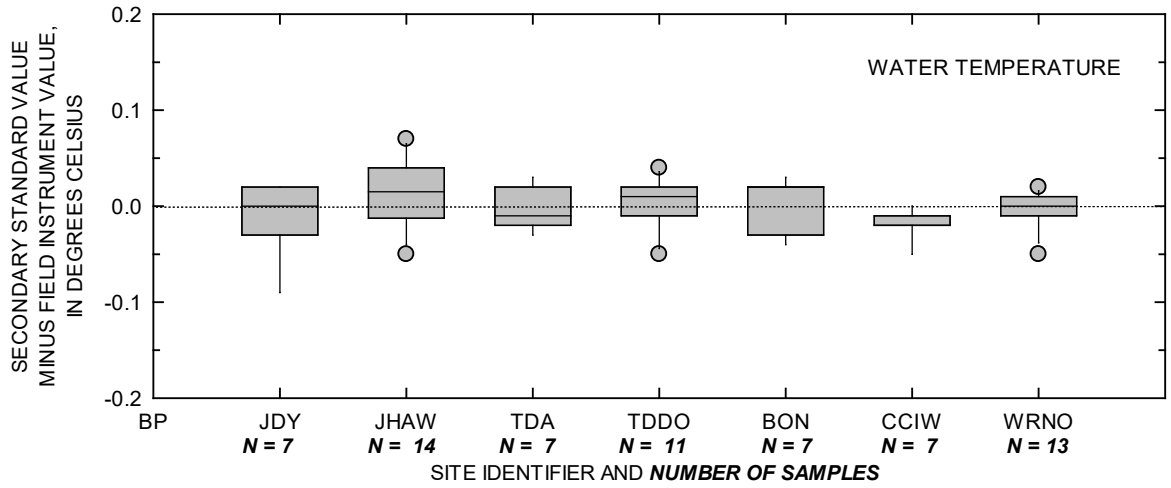

Figure G-4. Difference between the secondary standard and the field temperature instruments in the field after 3 or more weeks of deployment at seven stations in the lower Columbia River, Oregon and Washington, water year 2023. See figure G-2 for explanation of boxplots and table G-1 for definitions of station identifiers.

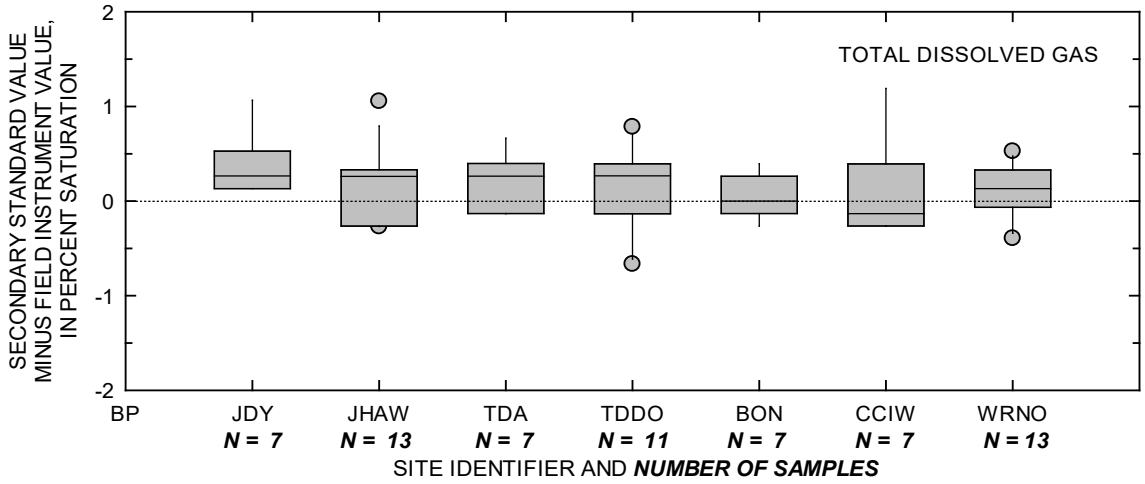

Figure G-5. Difference between the secondary standard and the field total-dissolved-gas instruments in the field after 3 or more weeks of deployment at seven stations in the lower Columbia River, Oregon and Washington, water year 2023. See figure G-2 for explanation of boxplots and table G-1 for definitions of station identifiers.

Table G-4. Summary of total-dissolved-gas side-by-side reference and field instrument comparisons, water year 2023.

Date	Reference sonde number.	Site sonde number	Barometric pressure (mmHg)				Water temperature (°C)				Pressure, total dissolved gas (mmHg)				
			Reference barometer	Site barometer	Differ -ence	Absolute difference	Reference sensor	Site sensor	Differ-ence	Absolute difference	Reference sensor	Site sensor	Differ-ence	Absolute difference	Difference in percent saturation
John Day navigation lock (JDY)															
4/26/2023	65425	67858	754.0	754	0.0	0.0	10.10	10.13	-0.03	0.03	823	822	1	1	0.13
5/17/2023	65425	66624	753.9	754	-0.1	0.1	13.12	13.12	0.00	0.00	937	936	1	1	0.13
6/6/2023	65425	66624	751.0	751	0.0	0.0	18.96	19.05	-0.09	0.09	898	890	8	8	1.07
6/26/2023	65425	67858	750.2	750	0.2	0.2	18.09	18.07	0.02	0.02	796	794	2	2	0.27
7/18/2023	65425	48242	757.0	757	0.0	0.0	21.60	21.59	0.01	0.01	790	786	4	4	0.53
8/30/2023	65425	67858	756.7	757	-0.3	0.3	21.49	21.47	0.02	0.02	763	760	3	3	0.40
9/18/2023	65425	63023B	752.6	753	-0.4	0.4	20.62	20.62	0.00	0.00	755	753	2	2	0.27
Mean					-0.09	0.14			-0.01	0.02			3.0	3.0	0.40
Median					0.00	0.10			0.00	0.02			2.0	2.0	0.27
John Day tailwater (JHAW)															
10/3/2022	66363	67838	757.2	757	0.2	0.2	19.38	19.36	0.02	0.02	767	767	0	0	0.00
11/10/2022	66363	67857	766.2	766	0.2	0.2	12.29	12.32	-0.03	0.03	743	743	0	0	0.00
12/7/2022	65425	67838	763.1	763	0.1	0.1	7.19	7.18	0.01	0.01	785	783	2	2	0.26
1/3/2023	65425	67857	756.3	756	0.3	0.3	2.96	2.98	-0.02	0.02	740	738	2	2	0.26
1/31/2023	65425	67838	763.8	764	-0.2	0.2	3.71	3.69	0.02	0.02	756	754	2	2	0.26
2/21/2023	65425	67857	745.9	746	-0.1	0.1	3.62	-	-	-	771	-	-	-	-
3/1/2023	-	67838	-	-	-	-	-	-	-	-	-	-	-	-	-
4/6/2023	65425	64961	757.9	758	-0.1	0.1	6.84	6.85	-0.01	0.01	783	775	8	8	1.06
4/26/2023	65425	13123A	758.8	759	-0.2	0.2	10.07	10.01	0.06	0.06	867	869	-2	2	-0.26
5/17/2023	65425	13123B	754.1	754	0.1	0.1	13.25	13.21	0.04	0.04	947	949	-2	2	-0.27
6/6/2023	65425	47075	751.6	752	-0.4	0.4	16.76	16.75	0.01	0.01	899	896	3	3	0.40
6/26/2023	65425	13123B	753.8	754	-0.2	0.2	18.06	17.99	0.07	0.07	865	867	-2	2	-0.27
7/18/2023	65425	13123A	758.0	758	0.0	0.0	21.80	21.76	0.04	0.04	872	870	2	2	0.26
8/30/2023	65425	13123B	757.7	758	-0.3	0.3	21.55	21.52	0.03	0.03	838	880	-42	42	-5.54
9/18/2023	65425	13123A	754.7	755	-0.3	0.3	20.65	20.65	0.00	0.00	765	762	3	3	0.40
10/10/2023	65425	13123B	744.8	745	-0.2	0.2	18.04	18.09	-0.05	0.05	755	757	-2	2	-0.27
Mean					-0.07	0.19			0.01	0.03			-2.0	5.1	-0.26
Median					-0.10	0.20			0.02	0.03			1.0	2.0	0.13

Date	Reference sonde number	Site sonde number	Barometric pressure (mmHg)				Water temperature (°C)				Pressure, total dissolved gas (mmHg)				
			Reference barometer	Site barometer	Differ-ence	Absolute difference	Reference sensor	Site sensor	Differ-ence	Absolute difference	Reference sensor	Site sensor	Differ-ence	Absolute difference	Difference in percent saturation
The Dalles forebay (TDA)															
4/26/2023	65425	65427	760.7	761	-0.3	0.3	10.17	10.17	0.00	0.00	871	872	-1	1	-0.13
5/18/2023	65425	64961	755.1	755	0.1	0.1	13.32	13.33	-0.01	0.01	932	933	-1	1	-0.13
6/7/2023	65425	65427	751.9	752	-0.1	0.1	16.92	16.94	-0.02	0.02	916	911	5	5	0.66
6/26/2023	65425	64961	752.2	752	0.2	0.2	18.56	18.54	0.02	0.02	820	819	1	1	0.13
7/19/2023	65425	65427	758.8	759	-0.2	0.2	21.91	21.88	0.03	0.03	835	833	2	2	0.26
8/31/2023	65425	64961	753.9	754	-0.1	0.1	21.18	21.20	-0.02	0.02	781	778	3	3	0.40
9/19/2023	65425	65427	757.3	758	-0.7	0.7	20.00	20.03	-0.03	0.03	758	756	2	2	0.26
Mean					-0.16	0.24			0.00	0.02			1.6	2.1	0.21
Median					-0.10	0.20			-0.01	0.02			2.0	2.0	0.26
The Dalles tailwater (TDDO)															
10/3/2022	66363	64598	761.3	761	0.3	0.3	19.36	19.35	0.01	0.01	781	779	2	2	0.26
11/10/2022	66363	64596	767.1	767	0.1	0.1	12.34	12.35	-0.01	0.01	757	754	3	3	0.39
12/7/2022	65425	64598	764.1	764	0.1	0.1	6.94	6.90	0.04	0.04	761	755	6	6	0.79
1/31/2023	65425	64596	767.1	767	0.1	0.1	3.74	3.72	0.02	0.02	760	757	3	3	0.39
5/2/2023	65425	64598	751.7	752	-0.3	0.3	11.30	11.32	-0.02	0.02	883	884	-1	1	-0.13
5/18/2023	65425	64596	756.6	757	-0.4	0.4	13.44	13.43	0.01	0.01	963	960	3	3	0.40
6/6/2023	65425	64598	751.1	751	0.1	0.1	16.79	16.78	0.01	0.01	901	906	-5	5	-0.67
6/27/2023	65425	64596	756.1	756	0.1	0.1	18.23	18.21	0.02	0.02	857	860	-3	3	-0.40
7/18/2023	65425	64598	758.2	758	0.2	0.2	21.59	21.58	0.01	0.01	854	854	0	0	0.00
8/11/2023	-	64596	-	-	-	-	-	-	-	-	-	-	-	-	-
8/15/2023	-	64598	757.7	758	-0.3	0.3	-	-	-	-	-	-	-	-	-
8/22/2023	-	63023B	-	-	-	-	-	-	-	-	-	-	-	-	-
8/28/2023	65425	-	757.0	757	0.0	0.0	-	-	-	-	-	-	-	-	-
9/19/2023	65425	64598	760.1	760	0.1	0.1	20.10	20.15	-0.05	0.05	779	776	3	3	0.39
10/10/2023	65425	67858	747.1	747	0.1	0.1	18.27	18.28	-0.01	0.01	770	768	2	2	0.27
Mean					0.02	0.17			0.00	0.02			1	3	0.15
Median					0.10	0.10			0.01	0.01			2.0	3.0	0.27

Date	Reference sonde number	Site sonde number	Barometric pressure (mmHg)				Water temperature (°C)				Pressure, total dissolved gas (mmHg)				
			Reference barometer	Site barometer	Differ-ence	Absolute difference	Reference sensor	Site sensor	Differ-ence	Absolute difference	Reference sensor	Site sensor	Differ-ence	Absolute difference	Difference in percent saturation
Bonneville forebay (BON)															
4/6/2023	-	67480	-	-	-	-	-	-	-	-	-	-	-	-	-
4/27/2023	65425	48242	763.1	763	0.1	0.1	10.55	10.53	0.02	0.02	869	870	-1	1	-0.13
5/19/2023	65425	66626	761.1	761	0.1	0.1	13.70	13.67	0.03	0.03	940	938	2	2	0.26
6/7/2023	65425	48242	755.7	756	-0.3	0.3	16.81	16.80	0.01	0.01	902	901	1	1	0.13
6/27/2023	65425	66626	757.9	758	-0.1	0.1	18.58	18.56	0.02	0.02	812	814	-2	2	-0.26
7/20/2023	65425	66623	761.3	761	0.3	0.3	21.67	21.70	-0.03	0.03	839	839	0	0	0.00
8/31/2023	65425	66626	756.7	756	0.7	0.7	21.34	21.32	0.02	0.02	778	778	0	0	0.00
9/19/2023	65425	66623	760.8	761	-0.2	0.2	19.72	19.76	-0.04	0.04	769	766	3	3	0.39
Mean					0.09	0.26			0.00	0.02			0.4	1.3	0.06
Median					0.10	0.20			0.02	0.02			0.0	1.0	0.00
Cascade Island (CCIW)															
4/27/2023	65425	13022A	764.8	765	-0.2	0.2	10.54	10.56	-0.02	0.02	899	901	-2	2	-0.26
5/15/2023	65425	13022B	758.9	759	-0.1	0.1	13.46	13.46	0.00	0.00	939	940	-1	1	-0.13
5/24/2023	65425	13022A	-	762	-	-	14.29	14.34	-0.05	0.05	931	933	-2	2	-0.26
6/7/2023	65425	13022B	756.8	757	-0.2	0.2	16.78	16.80	-0.02	0.02	913	914	-1	1	-0.13
6/27/2023	65425	13022A	759.5	760	-0.5	0.5	18.61	18.62	-0.01	0.01	885	887	-2	2	-0.26
7/20/2023	65425	13022B	762.9	763	-0.1	0.1	21.68	21.70	-0.02	0.02	893	890	3	3	0.39
9/1/2023	65425	13022A	756.6	757	-0.4	0.4	21.36	21.37	-0.01	0.01	810	801	9	9	1.19
Mean					-0.25	0.25			-0.02	0.02			0.6	2.9	0.08
Median					-0.20	0.20			-0.02	0.02			-1.0	2.0	-0.13

Date	Reference sonde number	Site sonde number	Barometric pressure (mmHg)				Water temperature (°C)				Pressure, total dissolved gas (mmHg)				
			Reference barometer	Site barometer	Differ-ence	Absolute difference	Reference sensor	Site sensor	Differ-ence	Absolute difference	Reference sensor	Site sensor	Differ-ence	Absolute difference	Difference in percent saturation
Warrendale (WRNO)															
10/4/2022	66363	67855	763.5	764	-0.5	0.5	19.14	19.13	0.01	0.01	789	786	3	3	0.39
11/10/2022	66363	67856	771.9	772	-0.1	0.1	12.13	12.18	-0.05	0.05	758	758	0	0	0.00
1/3/2023	65425	67855	760.8	761	-0.2	0.2	3.35	3.35	0.00	0.00	758	755	3	3	0.39
1/25/2023	65425	67856	779.6	389	390.6	390.6	4.11	4.09	0.02	0.02	773	771	2	2	0.26
4/7/2023	65425	67855	758.2	759	-0.8	0.8	7.34	7.33	0.01	0.01	828	824	4	4	0.53
4/26/2023	65425	67856	766.0	766	0.0	0.0	10.23	10.22	0.01	0.01	895	898	-3	3	-0.39
5/19/2023	65425	67855	762.0	762	0.0	0.0	13.86	13.86	0.00	0.00	943	943	0	0	0.00
6/7/2023	65425	67856	757.9	758	-0.1	0.1	16.92	16.94	-0.02	0.02	917	915	2	2	0.26
6/26/2023	65425	67855	763.3	763	0.3	0.3	18.81	18.81	0.00	0.00	887	889	-2	2	-0.26
7/19/2023	65425	67856	761.4	762	-0.6	0.6	21.83	21.84	-0.01	0.01	899	900	-1	1	-0.13
9/1/2023	65425	67855	757.2	757	0.2	0.2	21.44	21.44	0.00	0.00	801	800	1	1	0.13
9/18/2023	65425	67856	763.7	764	-0.3	0.3	19.95	19.96	-0.01	0.01	787	786	1	1	0.13
10/10/2023	65425	67855	750.6	751	-0.4	0.4	18.07	18.08	-0.01	0.01	771	769	2	2	0.27
Mean					29.85	30.32			0.00	0.01			0.9	1.8	0.12
Median					-0.10	0.30			0.00	0.01			1.0	2.0	0.13

Table G-5. Summary of reference and site TDG sensor comparisons measured during lab calibrations, water year 2023.

USACE Station identifier	Site sonde number	Date checked	Soda test (Pass/Fail/N/A)	Reference Barometric pressure (mmHg)		Site sensor Total pressure (mmHg)		Difference between reference pressure and site sensor total pressure (percent saturation)		Calibrated (Y/N)	Pressure test (Pass/Fail/N/A)
				+0	+300	+0	+300	+0	+300		
JDY	67858	5/8/2023	P	755.8	1055.8	756	1056	-0.03	-0.03	N	P
JDY	66624	-	-	-	-	-	-	-	-	-	N/A
JDY	67858	7/10/2023	N/A	760.3	1060.3	761	1061	-0.09	-0.09	N	P
JDY	48242	7/24/2023	P	762.1	1062.1	762	1062	0.01	0.01	N	P
JDY	67858	9/12/2023	P	755.7	1055.7	756	1056	-0.04	-0.04	N	P
JDY	63023B	9/27/2023	P	761.3	1061.3	761	1060	0.04	0.17	N	P
JHAW	67838	10/12/2022	P	761.9	1061.9	762	1062	-0.01	-0.01	N	P
JHAW	67857	11/22/2022	P	767.1	1067.1	767	1067	0.01	0.01	N	P
JHAW	67838	12/19/2022	P	760.5	1060.5	760	1060	0.07	0.07	N	P
JHAW	67857	1/18/2023	P	764.8	1064.8	765	1065	-0.03	-0.03	N	P
JHAW	67838	2/10/2023	P	757.0	1057.0	757	1057	0.00	0.00	N	P
JHAW	67857	3/28/2023	P	756.0	1056.0	756	1056	0.00	0.00	N	P
JHAW	67838	3/28/2023	P	-	-	-	-	-	-	-	N/A
JHAW	64961	4/17/2023	P	754.8	1054.8	754	1054	0.11	0.11	N	P
JHAW	13123A	5/8/2023	P	755.8	1055.8	756	1056	-0.03	-0.03	N	P
JHAW	13123B	5/30/2023	P	758.8	1058.8	759	1059	-0.03	-0.03	N	P
JHAW	47075	6/21/2023	P	756.7	1056.7	755	1055	0.22	0.22	N	P
JHAW	13123B	7/10/2023	N/A	760.3	1060.3	760	1061	0.04	-0.09	N	P
JHAW	13123A	7/24/2023	P	762.2	1062.2	762	1062	0.03	0.03	N	P
JHAW	13123B	9/12/2023	**F**	755.7	1055.7	755	1056	0.09	-0.04	N	P
JHAW	13123A	9/27/2023	P	761.2	1061.2	761	1061	0.03	0.03	N	P
JHAW	13123B	10/30/2023	P	762.5	1062.5	761	1062	0.20	0.07	N	P
TDA	65427	5/8/2023	P	755.8	1055.8	756	1056	-0.03	-0.03	N	P
TDA	64961	5/30/2023	P	758.8	1058.8	758	1057	0.11	0.24	N	P
TDA	65427	6/21/2023	P	756.7	1056.7	757	1057	-0.04	-0.04	N	P
TDA	64961	7/10/2023	N/A	760.3	1060.3	760	1060	0.04	0.04	N	P
TDA	65427	7/24/2023	P	762.2	1062.2	763	1062	-0.10	0.03	N	P
TDA	64961	10/4/2023	P	762.6	1062.6	762	1063	0.08	-0.05	N	N/A
TDA	65427	10/4/2023	P	762.6	1062.6	763	1062	-0.05	0.08	N	N/A

USACE Station identifier	Site sonde number	Date checked	Soda test (Pass/Fail/N/A)	Reference Barometric pressure (mmHg)		Site sensor Total pressure (mmHg)		Difference between reference pressure and site sensor total pressure (percent saturation)		Calibrated (Y/N)	Pressure test (Pass/Fail/N/A)
				+0	+300	+0	+300	+0	+300		
TDDO	64598	10/12/2022	P	761.9	1061.9	761	1061	0.12	0.12	N	P
TDDO	64596	11/22/2022	P	767.1	1067.1	766	1066	0.14	0.14	N	P
TDDO	64598	12/19/2022	P	760.4	1060.4	759	1059	0.18	0.18	N	P
TDDO	64596	2/10/2023	P	757.0	1057.0	756	1055	0.13	0.26	N	P
TDDO	64598	5/8/2023	P	755.8	1055.8	755	1055	0.11	0.11	N	P
TDDO	64596	5/30/2023	P	758.7	1058.7	758	1058	0.09	0.09	N	P
TDDO	64598	6/21/2023	P	756.7	1056.7	756	1056	0.09	0.09	N	P
TDDO	64596	7/10/2023	N/A	760.3	1060.3	760	1059	0.04	0.17	N	P
TDDO	64598	7/24/2023	P	762.2	1062.2	761	1061	0.16	0.16	N	P
TDDO	64596	8/22/2023	**F**	759.6	1059.6	758	1058	0.21	0.21	N	P
TDDO	64598	8/22/2023	**F**	759.6	1059.6	758	1058	0.21	0.21	N	P
TDDO	63023B	9/27/2023	P	761.3	1061.3	761	1060	0.04	0.17	N	P
TDDO	64598	10/4/2023	P	762.5	1062.5	761	1061	0.20	0.20	N	P
TDDO	67858	10/30/2023	P	762.5	1062.5	762	1062	0.07	0.07	N	P
BON	67480	6/12/2023	N/A	755.2	1055.2	755	1055	0.03	0.03	N	P
BON	48242	5/8/2023	P	755.8	1055.8	756	1056	-0.03	-0.03	N	P
BON	66626	5/30/2023	P	758.7	1058.7	758	1058	0.09	0.09	N	P
BON	48242	6/21/2023	P	756.7	1056.7	757	1056	-0.04	0.09	N	P
BON	66626	7/10/2023	N/A	760.2	1060.2	760	1060	0.03	0.03	N	P
BON	66623	7/24/2023	P	762.2	1062.2	762	1062	0.03	0.03	N	P
BON	66626	9/12/2023	P	755.7	1055.7	755	1055	0.09	0.09	N	N/A
BON	66623	10/4/2023	P	762.6	1062.6	762	1062	0.08	0.08	N	N/A
CCIW	13022A	5/8/2023	P	754.9	1054.9	755	1055	-0.01	-0.01	N	P
CCIW	13022B	5/15/2023	N/A	-	-	-	-	-	-	N	N/A
CCIW	13022A	5/30/2023	P	758.6	1058.6	758	1058	0.08	0.08	N	P
CCIW	13022B	6/21/2023	P	756.8	1056.8	756	1056	0.11	0.11	N	P
CCIW	13022A	7/10/2023	N/A	760.2	1060.2	760	1060	0.03	0.03	N	P
CCIW	13022B	7/24/2023	P	762.2	1062.2	762	1062	0.03	0.03	N	P
CCIW	13022A	10/4/2023	P	762.6	1062.6	762	1063	0.08	-0.05	N	N/A

USACE Station identifier	Site sonde number	Date checked	Soda test (Pass/Fail/N/A)	Reference Barometric pressure (mmHg)		Site sensor Total pressure (mmHg)		Difference between reference pressure and site sensor total pressure (percent saturation)		Calibrated (Y/N)	Pressure test (Pass/Fail/N/A)
				+0	+300	+0	+300	+0	+300		
WRNO	67856	10/24/2021	P	736.8	1036.8	736	1036	0.11	0.11	N	P
WRNO	67855	12/8/2021	P	758.1	1058.1	758	1058	0.01	0.01	N	P
WRNO	67856	12/22/2021	P	748.1	1048.1	747	1047	0.15	0.15	N	P
WRNO	67855	1/28/2022	P	768.0	1068.0	768	1068	0.00	0.00	N	P
WRNO	67856	2/18/2022	P	769.1	1069.1	768	1068	0.14	0.14	N	P
WRNO	67855	3/25/2022	P	760.2	1060.2	760	1059	0.03	0.16	N	P
WRNO	67856	4/18/2022	P	751.1	1051.1	750	1049	0.15	0.28	Y	P
WRNO	67855	5/4/2022	P	759.4	1059.4	759	1059	0.05	0.05	N	P
WRNO	67856	5/26/2022	P	753.2	1053.2	753	1054	0.03	-0.11	N	P
WRNO	67855	6/10/2022	P	756.7	1056.7	756	1056	0.09	0.09	N	P
WRNO	67856	6/28/2022	P	760.8	1060.8	761	1061	-0.03	-0.03	N	P
WRNO	67855	8/18/2022	P	755.0	1055.0	755	1055	0.00	0.00	N	N/A
WRNO	67856	9/27/2022	P	755.0	1055.0	755	1055	0.00	0.00	N	P
WRNO	67855	10/12/2022	P	761.8	1061.8	761	1061	0.11	0.11	N	P