Site C Clean Energy Project

Site C Total Dissolved Gas Monitoring Program (Mon-11)

Construction Year 9 (2023)

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REPORT

Site C Total Dissolved Gas Monitoring Program (Mon-11) - 2023 Investigations

Site C Clean Energy Project

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LIST OF ABBREVIATIONS

Acronym	Description
AIC	Akaike's Information Criterion
Array	Site C Total Dissolved Gas Monitoring sites that are collectively referred to as an 'Array'
DCP	Data Collection Platform
EIS	Site C Environmental Impact Statement
FAHMFP	Site C Fisheries and Aquatic Habitat Monitoring and Follow-up Program
GBD	Gas Bubble Disease
masl	metres above sea level
Mon-11	Site C Total Dissolved Gas Monitoring Program
PCD	Peace Canyon Dam
Project	Site C Clean Energy Project
RMU	Remote Monitoring Unit
SMS	Short Message Service
TDG	Total Dissolved Gas
WSC	Water Survey of Canada

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1.0 INTRODUCTION

Monitoring of total dissolved gas (TDG) at the Site C Clean Energy Project (the Project) is conducted by the Site C TDG Monitoring Program (Mon-11), a component of BC Hydro's Site C Fisheries and Aquatic Habitat Monitoring and Follow-up Program (FAHMFP; BC Hydro 2015). TDG is air dissolved in water and is commonly expressed as a percentage of the amount of air that water will hold when it is in equilibrium (100%) with the atmosphere at ambient water surface conditions (BC Hydro 2014, 2022). When air bubbles are entrained in water and the air-water mixture is carried to a substantial depth, entrained air dissolves into solution due to hydrostatic pressure, resulting in water that is supersaturated with gas relative to equilibrium at surface (atmospheric) pressure.

Elevated TDG and supersaturation is a common issue downstream of hydroelectric facilities (McGrath et al. 2006). The amount of air entrained as water flows through or over infrastructure, and the resulting amount of TDG and supersaturation, can depend on the discharge, as well as the type, dimensions, and configuration of the water conveyance structures (Li et al. 2022). Water temperature is also known to be an important driver of TDG (AlOMar et al. 2020). As water moves downstream, the amount of TDG can be affected by dissipation back to atmosphere, mixing of water in the river channel, and dilution from tributaries (Li et al. 2022). Primary productivity, which generates oxygen through photosynthesis, can also influence TDG downstream and upstream of hydroelectric facilities (McGrath et al. 2006; Demars et al. 2021).

Discharge from the Project may result in increased TDG pressure in the Peace River downstream of the Project. Additional background information on TDG is available in WSP (2023) and BC Hydro (2014). Elevated TDG may lead to negative effects on fish due to gas bubble disease (GBD). GBD is a condition where supersaturated gas that has been absorbed by a fish comes out of solution and forms bubbles in the fish's blood or tissues, which can result in injury and possibly death. Weitkamp (2008) provides a summary of the biological effects of GBD on fish.

Symptoms of GBD can be mitigated by hydrostatic pressure if fish reside at a water depth where hydrostatic pressure equals or exceeds the TDG pressure, referred to as the "compensation depth". The hydrostatic pressure provided by one metre of water depth compensates for an approximately 10% incremental increase in TDG above ambient pressure (e.g., 1 m of depth compensates for 110 TDG% [percent TDG]; 2 m of depth compensates for 120 TDG%, and so on). Fidler and Miller (1997) defined the risk to aquatic life from GBD as Low when TDG is below 110 TDG% and defined the risk as High when TDG is 120 TDG% or higher, especially for fish and aquatic life that are constrained to shallow water habitat (e.g., a small side channel).

In 2022, a pilot TDG monitoring study was conducted to obtained baseline TDG data downstream of the Project (WSP 2023). In 2023, information and lessons learned during this 2022 pilot study were used to develop the Site C TDG Monitoring Array ("the Array"). The Array is a collection of five TDG monitoring stations positioned downstream of the Project that continuously record TDG levels in the Peace River. Data collected by the Array will be used by the FAHMFP) to answer the following management questions, which are detailed in the FAHMFP's Site C Total Dissolved Gas Monitoring Program (Mon-11):

1) Do TDG levels in the Peace River downstream of the Project stay within predictions from the EIS [Environmental Impact Statement] during the reservoir filling phase of Project construction and Project operation or increase downstream of the Project relative to the forebay?

2) If TDG levels downstream of the Project exceed predictions, are adverse effects to fish survival observed?

The objectives of the 2023 report were to describe the components, location, design, and operation of the Array, summarize the TDG and water temperature data collected in 2023, and conduct a preliminary assessment of variables affecting TDG downstream of the Project. Data were summarized tabularly and graphically and compared to Peace River flows. The total duration that TDG levels were recorded within specified TDG ranges, based on TDG threshold limits, were summarized (Section 3.0). Statistical models were used to investigate which variables influenced TDG concentrations downstream of the Project in 2023 (Section 4.0).

Data collected in 2023 represent conditions downstream of the Project while flow of the Peace River was conveyed through the Project via two diversion tunnels prior to reservoir filling and Project operation. During the 2023 study period, modifications were made to one of the diversion tunnels in preparation for reservoir filling. From 1 January to 14 June, Peace River flows were passed through the Project using two diversion tunnels. From 15 June to 13 October, Diversion Tunnel 2 was closed while it was being modified and the entire Peace River flow was passed through Diversion Tunnel 1. From 14 October to the end of the 2023, Peace River flow was passed through both Diversion Tunnel 1 and the newly converted Diversion Tunnel 2. These modifications altered flow characteristic downstream of the Project, which should be considered when interpreting 2023 results.

2.0 THE SITE C TDG MONITORING ARRAY

2.1 Station Locations

The Array consists of five TDG monitoring stations, with three stations located in the 16 km long section of the Peace River between the Project and the Pine River's confluence with the Peace River, and two stations located approximately 36 km downstream of the Project (Table 1; Figure 1 and Figure 2). Three different styles of station were used in the Array: shore-based stations; buoy-based stations, and sonde-based stations. The station type deployed depended on the conditions at each site location, as well as the need for real-time, continuous data uploads versus archival loggers that required downloading, as described further below.

Table 1: Site C TDG Monitoring Array station names, station type, data type and use, and location.

Station Name	Station Type	Data Type[a]	Data Use	Zone	Easting	Northing
Stn_106.8R	Shore-based	Real-time, Continuous	Monitor TDG immediately downstream of the Project on the right bank	10V	630652	6229298
Stn_107.1L	Shore-based	Real-time, Continuous	Monitor TDG immediately downstream of the Project on the left bank	10V	630939	6229642
Stn_112.5L	Shore-based or Buoy-based	Real-time, Continuous	Backup TDG data and verification of Stn_106.8L and Stn_107.1R data	10V	636351	6230367
Stn_134.5L	Sonde	Manual Field Download, Continuous	Monitoring TDG downstream of the Peace-Pine confluence	10V	655254	6222302
Stn_136.5R	Sonde	Manual Field Download, Continuous	Monitoring TDG downstream of the Peace-Pine confluence	10V	657081	6221576

[a] Data recorded by shore-based and buoy-based stations are uploaded hourly to the Array DCP, as described in Section 2.2.1; Sonde stations are autonomous data loggers that must be downloaded by field personnel.

Stations were named based on river kilometre (RKm) of the Peace River as measured downstream from WAC Bennett Dam (RKm 0.0). Stn_107.1L and Stn_106.8R were located along the left and right banks of the Peace River, respectively, as viewed facing downstream, approximately 1 km downstream of the Project. Stn_112.5L was deployed on the left bank approximately 7 km downstream of the Project. Stn_107.1L and Stn_106.8R were intended to record TDG immediately downstream of the Project and identify differences in TDG along the left and right banks that may be associated with generation and spill discharge during dam operations. Data from Stn_112.5L were used as backup data and to provided comparison to upstream stations (e.g., to assess accuracy or identify discrepancies in data between stations). All three stations were shore-based stations and were suitable for year-round TDG monitoring. If required, a buoy-based station can be deployed at Stn_112.5L as a replacement/backup. Stn_106.8R and Stn_107.1L were accessible by road; however, servicing of Stn_112.5L, or the removal of in-river components at any of the three stations requires a boat-based field crew. A full description of the shore-based and buoy-based TDG station designs are provided in Sections 2.2.1.1 and 2.2.1.2.

Two additional TDG stations, Stn_134.5L and Stn_136.5R, were installed near the left and right banks of the Peace River, respectively, approximately 30 km downstream of the Project. Each of these two stations consisted of an automatous TDG data sonde that recorded continuous data at 15-minute intervals. On-site data downloads and servicing of these stations required a boat-based field crew. A full description of the sonde-based TDG station design is provided in Section 2.2.2. Data collected at these sonde-based stations are intended to provide insight regarding how TDG levels changed due to the effects of dilution and dissipation with distance downstream of the Project.

LEGEND

- TOTAL DISSOLVED GAS MONITORING LOCATION,
- WSC PEACE ABOVE
- RIVER KILOMETRE AS MEASURED DOWNSTREAM FROM W.A.C. BENNETT DAM
- ROAD

0 1 2

1:75,000 KILOMETRES

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DATUM: NAD83 PROJECTION UTM10

CLIENT
BC HYDRO

PROJECT
SITE C CLEAN ENERGY PROJECT

CONSULTANT

YYYY-MM-DD	2024-03-12
DESIGNED	PG
PREPARED	JG
REVIEWED	PG
APPROVED	PG

TITLE
THE SITE C TDG MONITORING ARRAY STATIONS STN_106.8R, STN_107.1L, AND STN_112.5L UPSTREAM OF THE PEACE-PINE CONFLUENCE

PROJECT NO.	CONTROL	REV.	FIGURE
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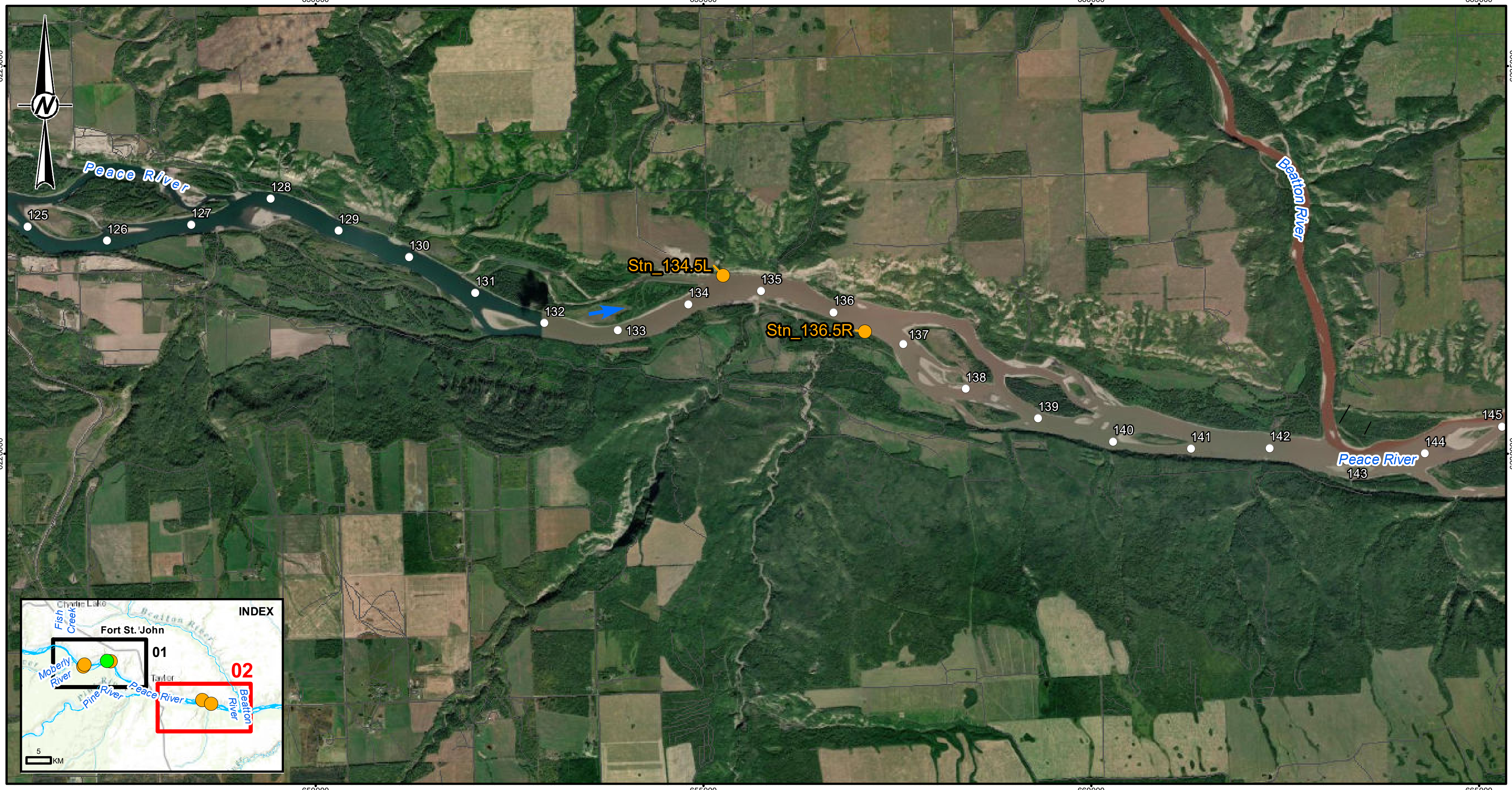

LEGEND

- TOTAL DISSOLVED GAS MONITORING LOCATION,
- WSC PEACE ABOVE
- RIVER KILOMETRE AS MEASURED DOWNSTREAM FROM W.A.C. BENNETT DAM
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0 1 2

1:75,000 KILOMETRES

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CLIENT
BC HYDRO

PROJECT
SITE C CLEAN ENERGY PROJECT

CONSULTANT

YYYY-MM-DD	2024-03-12
DESIGNED	PG
PREPARED	JG
REVIEWED	PG
APPROVED	PG

TITLE
THE SITE C TDG MONITORING ARRAY STATIONS STN_134.5L AND STN_136.5R DOWNSTREAM OF THE PEACE-PINE CONFLUENCE

PROJECT NO.	CONTROL	REV.	FIGURE
20136470	2023.23.1G	0	02

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2.2 Station Design

2.2.1 Data Collection Platform

A Data Collection Platform (DCP) was used by all real-time TDG stations (i.e., the shore-based and buoy-based stations). These stations were equipped with a ReliLink™ Solution/Connect™ DCP system (formerly GolderWatch®/GoldConnect™) and were designed and fabricated by Sullivan Telemetry LLC dba ReliLink™ in association with WSP USA Inc. based in Denver, Colorado. The general design and specifications of the DCP were as follows:

- The DCP consisted of a ReliLink™ remote monitoring unit (RMU) with hardwire connections to the TDG probe, a satellite modem and antenna, and an onboard battery power supply.
- The RMU powered and recorded data from the TDG probe.
- Data stored within the RMU memory buffer were transmitted over a satellite connection to the Connect™ cloud-based server.
- Through Connect™, data were queried and plotted for review, analyzed, and exported. Station status and functionality were monitored by staff and automated email and Short Message Service (SMS) text message alerts were created based on user-defined criteria (e.g., loss of connection, low battery voltage, high TDG).
- When required, administrators conducted over-the-air programming of the RMU to change data recording and transmission time intervals. During the 2023 study period, all stations were programmed to recorded data in 15-minute intervals and data were uploaded to the Connect™ cloud-based server once per hour.
- During periods of prolonged communication failure (i.e., greater that 2-hours), Connect™ was programed to send automated notifications (email or SMS message) to technical staff. Notifications continued every 2-hours until communication was re-established, at which point the alert was cancelled and an alert cancellation notification was sent. The onboard RMU was capable of storing up to a maximum of 7-days of 15-minute interval data, after which data-logging stops.

A schematic detailing the configuration of the TDG probe and DCP components during the 2023 study are outlined in Figure 3.

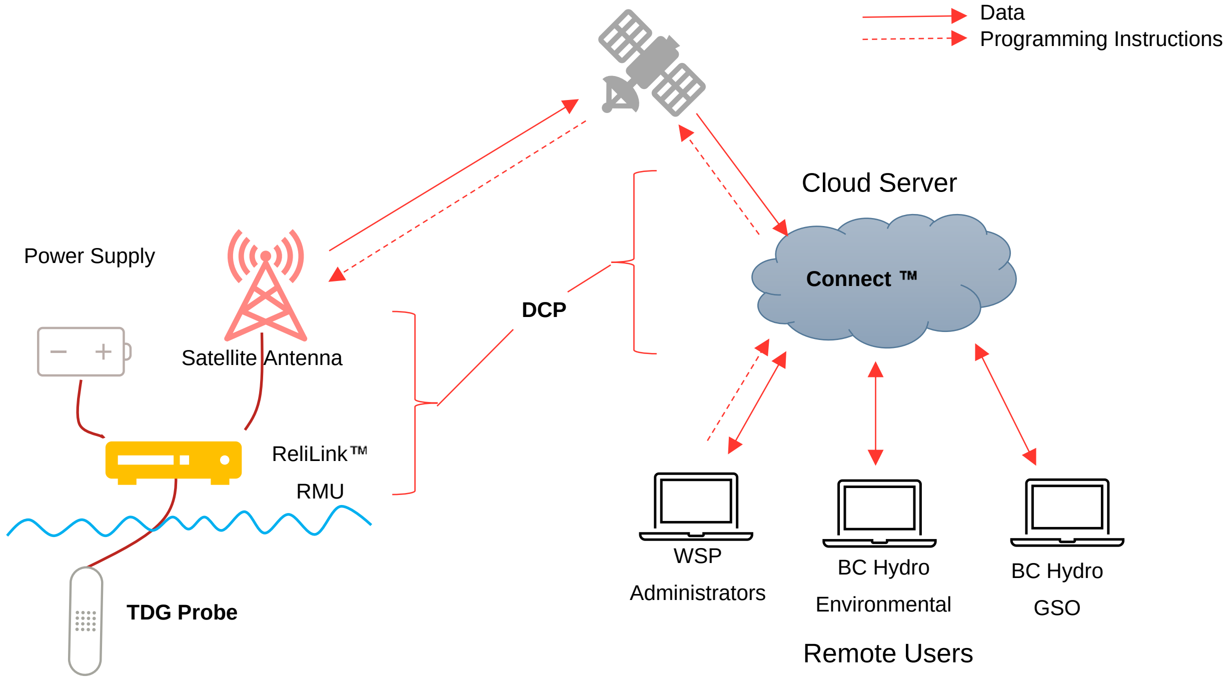

Figure 3:A schematic of the design of the DCP and TDG equipment used at real-time TDG monitoring stations as part of the Site C TDG Monitoring Array, 2023.

2.2.1.1 Shore-based TDG Station Components and Design

Shore-based TDG stations were installed at the three most upstream locations (i.e., Stn_106.8R, Stn_107.1L, and Stn_112.5L). A generalized description of a shore-based TDG station is provided in Figure 4. Each shore-based TDG station consisted of the following components:

- a Pro-Oceanus Solu-Blu™ TDG probe (Pro-Oceanus Systems Inc., Bridgewater, Nova Scotia) equipped with a 35 m long cable.
- a 30 kg custom-designed ballasted steel anchor housing on which the TDG probe was deployed in the river.
- a steel weather-resistant cabinet, positioned on shore above the annual highwater mark, to house the station DCP and station power supply.

Shore-based TDG stations were expected to operate year-round and, compared to a buoy-based station, offered more protection for the DCP electronics, the battery power supply, and the cable connections between the DCP and TDG probe. The TDG probe was capable of measuring both TDG and water temperature. It was attached to the ballasted steel anchor housing and was deployed by boat below the water surface and positioned, where possible, to protect it from floating debris and ice. The cable between the probe and cabinet was deployed within a length of 1” (2.54 cm) diameter aluminum flex-conduit, entrenched into the ground, starting from where the cable exited the weather-resistant cabinet to a point several metres towards the thalweg from the low-flow wetted perimeter of the river. The conduit protected the probe cable from abrasion, weathering, and other damage (e.g., chewing by beavers or porcupines, an issue reported on other TDG programs on the Peace River).

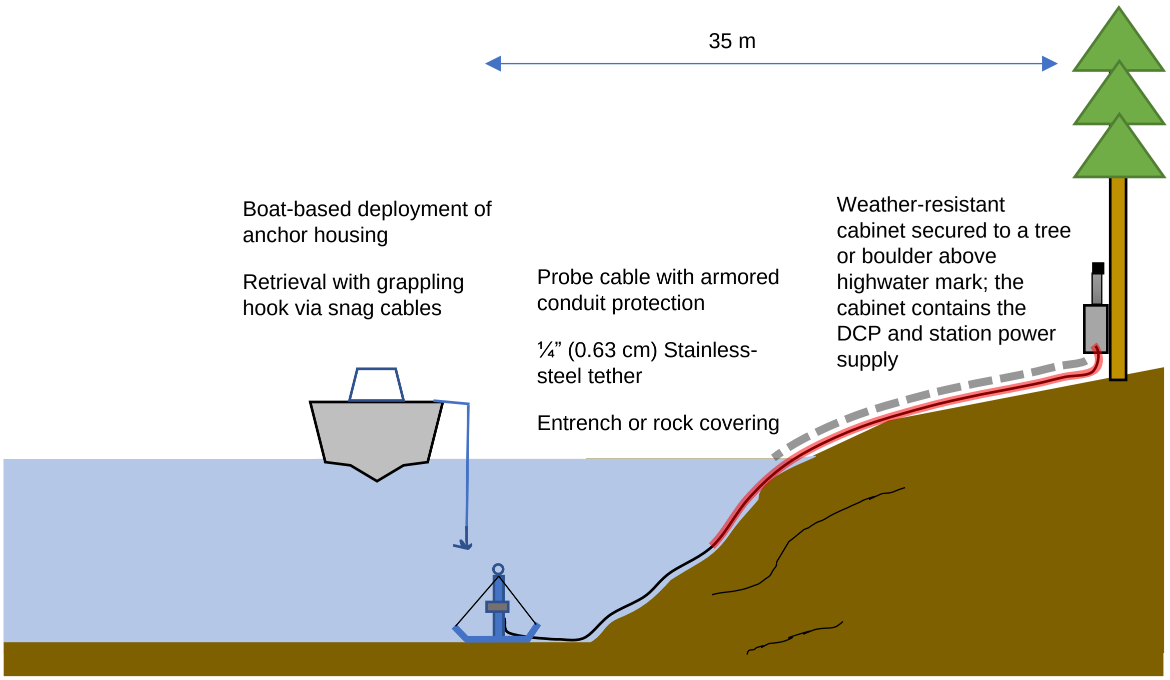

Figure 4: Stylized illustration of the components and design of a shore-based TDG station, 2023.

Shore-based station TDG probe

The shore-base stations were each equipped with a Pro-Oceanus Solu-Blu™ TDG probe with the following attributes:

- The Pro-Oceanus Solu-Blu™ TDG probe used a semipermeable membrane called Enduraflux™, which was developed by Pro-Oceanus specifically to measure TDG.
- The TDG sensor's accuracy was ±0.1TDG%; the TDG sensor's resolution was 0.1TDG% saturation level; and the TDG sensor's measurement range was 75 to 150 TDG%.
- The water temperature measurement range was 0°C to 35°C.
- The probe contained a vented (air referenced) internal barometer used to record barometric pressure, which allowed the calculation of percent saturation as an output parameter.
- Data outputs of the Solu-Blu™ TDG probe included water temperature, barometric pressure, total gas pressure, and percent TDG.
- All parameters were output as a single data stream for transmission to the DCP.
- Factory calibration and maintenance of the probe are recommended every three years.

Ballasted steel anchor TDG probe housing

At each shore-based station, the Pro-Oceanus Solu-Blu™ TDG probe was deployed in the river on a 30 kg custom-welded ballasted steel anchor housing (Figure 5). The anchor had the following attributes:

- Bottomed weighted with a wide mesh base to allow the housing to remain upright, keeping the TDG probe within the water column and preventing submersion of the housing when deployed in soft substrate.
- Horizontal probe mount to prevent accumulation of debris and sediment on the TDG probe membrane.
- Integrated stainless steel cable snag lines to facilitate retrieval via a grappling hook.
- Welded cable and rope attachment points for a TDG probe strain relief and to facilitate deployment.
- Secured to shore with a 25-30 m long ¼” stainless-steel cable.

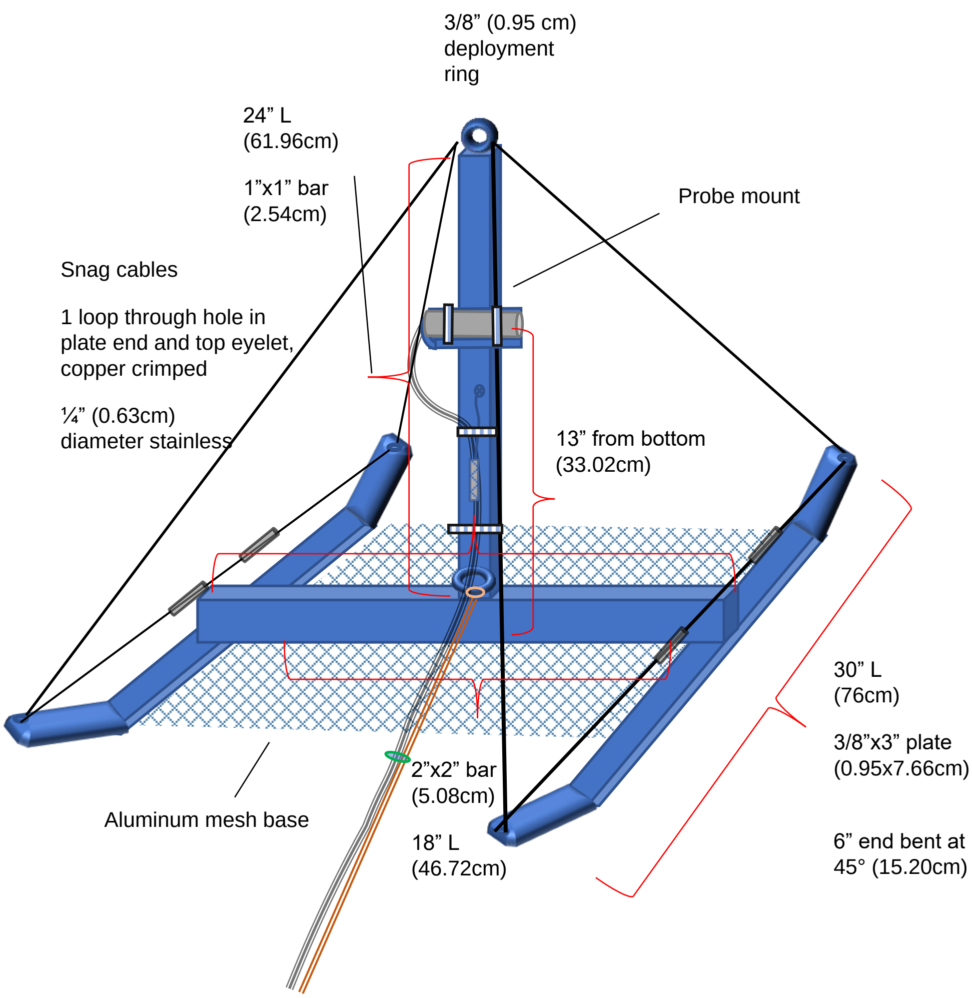

Figure 5: A schematic of the steel ballasted anchor mooring to secure and orient a Solu-Blu™ TDG probe at shore-based TDG stations, 2023.

Weather-resistant cabinet of shore-based station

At each shore-based station, a weather-resistant cabinet, manufactured by Saginaw Control and Engineering (Saginaw, MI), was installed above the highwater mark and secured to either a tree (Stn_106.8R and Stn_112.5L) or to a 3” (7.62 cm) diameter galvanized pipe mounted to a large piece of rip-rap (Stn_107.1L). The cabinet housed major components of the DCP (e.g., the RMU, power supply, and connectors) (Figure 6). The cabinets had the following attributes:

- The cabinet dimensions were 20” wide by 24” tall by 6” deep (50.8cm x 61.0cm x 15.2cm).
  - Heavy gauge metal-walled construction.
  - Venting to ensure equilibrium between the cabinet interior and outside, allowing changes in barometric pressure to be detected.
- A lockable metal access door with a weather-resistant O-ring seal equipped with door edge hold-downs.
- Top and bottom Unistrut™ braces to allow mounting.
- The TDG probe cable entered the cabinet through a 1” diameter hole in the bottom of the cabinet; a length of aluminum and PVC flex conduit was used to protect the probe cable.
- The weather-resistant cabinet housed the RMU, a top mounted satellite antenna, power supply, barometric pressure air reference line desiccant, and excess probe cable.
  - A sealed Iridium satellite antenna (Iridium Communications Inc., McLean, VA) was mounted on a mast on top of the box.
  - The RMU was housed in a secondary waterproof housing within the cabinet.
  - The TDG probe was connected to the RMU with a 4-wire molex connectors; the power supply was connected to the RMU with a screw-style 3-pin connector.
  - The station’s battery power supply consisted of 36 AA Energizer Lithium Ultimate batteries sealed in a fully waterproof container equipped with double O-rings and desiccant, to control humidity. The batteries were configured in 6 parallel banks of 6 cells, linked in series in each bank, to produce 9.0 V and an approximate battery capacity of 12,000 mAh. Station battery life was estimated at between 3 and 4 months.
  - The TDG probe’s barometric air reference line entered the cabinet with the probe cable and was protect by the flex conduit. An inline desiccant cartridge inside the cabinet was used to control humidity and prevent water blockages from forming in the air reference line.
- The cabinet was secured with a cut-resistant lock.
- A label, affixed to the cabinet door, identified that the equipment was for scientific research and provided a local contact phone number.

Figure 6: An example of a weather-resistant cabinet at a shore-based TDG station (left inset; Stn_112.5L) deployed as part of the Site C TDG Monitoring Array, 2023. The interior of the cabinet and the components housed within the cabinet are shown in the right inset.

2.2.1.2 Buoy-Based TDG Station Components and Design

Buoy-based stations can be deployed at locations with low water velocity and sufficient depth to prevent contact between the station and the river bottom as water levels fluctuate. During the 2023 study, a buoy-based station was temporarily deployed at Stn_112.5L between 2 August and 23 October. Stn_112.5L is located in a large back eddy where water velocity is low and water depth ranges between 3 to 6 m deep. The buoy station consisted of a custom-designed NexSens CB-25 Data Buoy (NexSens Technology, Inc., Fairborn, OH) to house the DCP and TDG probe components. These components were attached to either the top of the buoy, within the interior of the buoy's central canister, or attached to the bottom of the buoy as described as follows (**Error! Reference source not found.**):

- A Pro-Oceanus Solu-Blu™ TDG probe with a 3 m long probe cable was deployed at the bottom of a 1.5 m long stainless-steel instrument tube secured to the bottom of the buoy. The instrument tube was attached in the center canister base plate of the buoy. The probe cable was routed up through the buoy to connect to the DCP and power supply. With the exception of the cable length, the TDG probe in the buoy was identical to the TDG probe specifications used in the shore-based stations (Section 2.2.1.1).
- The length of the TDG instrument tube (1.5 m) was designed to keep the TDG probe sensor below the TDG compensation depth, below which air bubbles would not be expected to form on the TDG probe sensor, based on the anticipated levels of TDG expected during the construction and operation of the Project[1].

[1] Site C EIS, Volume 2, Section 12.4.3.4.

- Paired in-line desiccant tubes on an elevated mount were used to control condensation and reduce the risk of water blockages in the TDG probe air reference line.
- The DCP RMU and connectors were housed in a clear acrylic cylinder and secured within the interior of the buoy canister with a top plate. The DCP housing was sealed with two double O-ring end caps. The end cap affixed to the top plate contained the TDG probe connector, power connector, and an Iridium satellite antenna (Iridium Communications Inc., McLean, VA). Desiccant and a moisture indicator strip were added to the cylinder housing and the housing was sealed with double O-ring end caps.
- The power supply was identical to the shore-based station power supply and was mounted on an aluminum bracket to position the power supply above the water surface. Station battery life was estimated at between approximately 3 and 4 months.
- An active radio telemetry tag was affixed to the buoy to allow the station to be located by radio telemetry if needed.
- Components on the top of the buoy were protected from weathering and UV damage by a fabric cover.
- Around the instrument tube, at the base of the buoy, a floatation ring and up to five 2” (5.08cm) thick closed-cell foam floats were used to provide additional buoyancy and stability. The additional flotation kept the station components on the top of the buoy (i.e., the power supply and desiccant tubes) higher above the water surface and helped keep the station oriented vertically in the water column.
- A mooring bungee connected between the bottom of the instrument tube to a 100 lb (45.4 kg) pyramid anchor was used to secure and position the buoy station within the eddy. With changes in water level elevation, the mooring bungee would either stretch or contract. A stainless-steel cable was used to secure the pyramid anchor to shore.

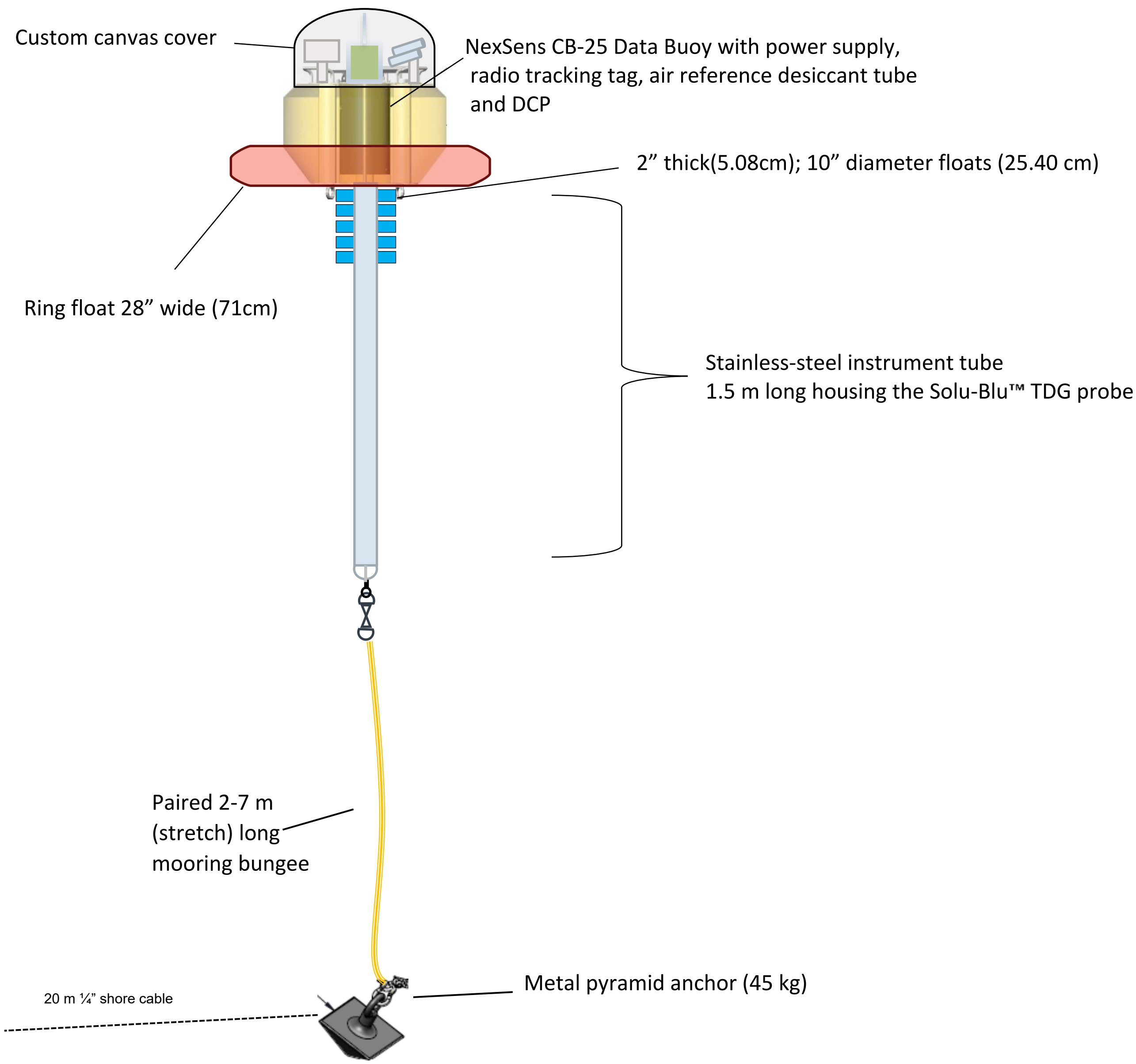

Figure 7: A schematic of a buoy-based TDG monitoring station deployed as part of the Site C TDG Monitoring Array, 2023.

2.2.2 Sonde-based TDG Monitoring Station

Sonde-based TDG stations were deployed at Stn_134.5L and Stn_136.5R downstream of the Peace-Pine confluence. The sonde-based stations recorded continuous TDG and water temperature readings at 15-minute intervals. These stations were not equipped with a DCP and could not be queried remotely. As such, data recorded at these stations were downloaded manually by field staff. Sonde-based stations were deployed at these two locations because there was less need for real-time, continuous data, compared to stations closer to the Project, and because deployment of the Sonde-based stations was more feasible at the selected monitoring locations because of site conditions and access.

Each sonde-based station consisted of the following components:

- A Pro-Oceanus Mini TDGP™ (Pro-Oceanus Systems Inc., Bridgewater, Nova Scotia) with the following attributes:
  - The Pro-Oceanus Mini TDGP™ used a semipermeable membrane called Enduraflux™, which was developed by Pro-Oceanus specifically to measure TDG.
  - The TDG sensor's accuracy was ±0.1% (mbar); the TDG sensor's resolution was 0.002% of full scale (4 mbar); and the TDG sensor's measurement range was 0 to 2000 mbar.
  - The water temperature measurement range was from -2°C to 50°C.
  - The outputs of the Mini TDGP™ sonde included water temperature, total gas pressure, and battery voltage.
  - The Mini TDGP™ sonde did not record barometric pressure. During data review and processing, regional barometric pressure data, adjusted for elevation, and total gas pressure were used to calculate percent TDG saturation as an output parameter.
  - The Mini TDGP™ sonde was equipped with an internal rechargeable 5 Amp-hour battery. For the 15-minute log interval used during the 2023 study, the internal memory and battery power was of sufficient capacity to allow the unit to record data for up to 18 months.
  - Due to calibration stability of the TDG sensor, factory calibration and maintenance are recommended every three years.
- The Pro-Oceanus Mini TDGP sensor was mounted to a steel-ballasted anchor housing, identical to the housings used at the shore-based station (Section 2.2.1.1), and the anchor was secured to shore using a length of stainless-steel cable.

2.3 Installation, Servicing, and Maintenance

The Array was installed in June 2023 and subsequently modified and serviced opportunistically from August to October.

2.3.1 Station Installation – 5–12 June

The main objectives during the installation session were to test the functionality of the station equipment, assemble the station components, determine the final location of each of the stations, and install the stations and ensure connectivity of the stations' DCP. Although the station components of each station type (i.e., shore-based, buoy-based, and sonde-based) were similar, each station required site-specific customization due to different site attributes.

Tests were conducted on all TDG probes and sondes to confirm they worked properly and to identify differences between units. This testing demonstrated that, once the probes attained operational status, they were highly responsive and required less than 1 minute to respond to minor changes in TDG levels. Testing also demonstrated that the length of time needed for a probe to reach equilibrium and begin providing accurate readings varied for individual probes and varied by probe style (i.e., Pro-Oceanus Solu-Blue TDG probes and Mini TDGP sondes); these times ranged between 15 minutes and 3 hours. For this reason, data collected immediately after initial probe deployment were typically excluded from data summaries and analysis.

Both Stn_106.8R and Stn_107.1L were successfully installed and connected to the DCP, providing near real-time remote access to their data. Both stations were deployed during low flow conditions (i.e., between 445 and 485 m^3/s), and both stations were expected to remain submerged under all anticipated flow conditions. Stn_106.8R was deployed at a total water depth of 1.5 m and at a location that would likely experience moderate water velocities during higher Peace River flows. The deployment site selected for Stn_106.8R was the deepest location available within reach of the shore-based components. The Stn_107.1L probe was positioned at a depth of 2.0 m in the backwater of a medial bar that partially protected the probe from main channel flows. The sonde-based stations were successfully installed at Stn_134.5L and Stn_136.5R. Stn_134.5L was positioned in a sheltered backwater at a depth of 1.3 m. Stn_136.5R was positioned at the downstream end of a point bar at a depth of 1.1 m. The two sonde deployment locations were the deepest nearshore locations that were identified at the time of deployment.

The buoy-based TDG station was assembled to allow rapid deployment of the buoy station in the event of a station failure, but it was not deployed during the June session.

2.3.2 Station Service – 1–2 August

A review of preliminary TDG data recorded at Stn_106.8R and Stn_107.1L in June and July indicated that the TDG sensor at each station was becoming less responsive. Stn_106.8R and Stn_107.1L sensor readings also diverged from each other and changes in TDG detected by Stn_106.8R were not always detected at Stn_107.1L. This discrepancy between station readings was attributed to sediment build up on the TDG sensor, which was oriented slightly upward to prevent air from being trapped on the sensor surface and to reduce the profile of the station, under the assumption that flow would be sufficient to scour and remove any sediment build up on the membrane. During the 1-2 August service visit, sediment accumulation was evident on some of the shore-based TDG sensors (Stn_106.8R and Stn_107.1L) as well as the sonde stations (Stn_134.5L and Stn_136.5R). Due to this sediment accumulation, TDG data recorded at each station between initial deployment and the 1-2 August service visit were likely not representative of actual TDG levels and TDG data recorded by the array from 5 June to 1 August were excluded from analyses.

At all stations, new probe mounts were installed to orient the TDG sensor horizontally to prevent sediment build up. After installation of the horizontal probe mounts, subsequent real-time TDG data recorded at Stn_106.8R and Stn_107.1L indicated that the station sensors were responsive and that the change in probe orientation likely resulted in a reduction of sediment build-up on the TDG sensor.

Due to difficulties and data loss experienced at Stn_106.8R and Stn_107.1L in June and July, a buoy-based TDG station was installed at Stn_112.5L to provide a third TDG data reference downstream of the Project. The buoy-based TDG station was deployed on the left downstream bank, adjacent to the main channel, in the center of a back eddy where water velocity was low. The buoy station anchor was deployed at a depth of 4.3 m.

2.3.3 Station Service – 9–19 August

After initial deployment of Stn_112.5L on 2 August, the station failed to connect with the DCP. The station was retrieved on 9 August and returned to the Fort St John WSP office for inspection. At the office, the station was dismantled and the DCP component was tested and both the RMU and satellite antenna were replaced, both of which were found to be working only intermittently. With the new components installed, the station was reassembled, tested, and successfully connected to the DCP. The buoy-based TDG station was redeployed on 19 August.

2.3.4 Station Service – 23 August

The sonde-based TDG stations at Stn_134.5L and Stn_136.5R were downloaded to ensure that changes in sonde orientation implemented during the 2 August service visit resulted in improved sensor readings and to confirm that data were logging successfully. During this service visit, sediment was not evident on the TDG sensor of either station and all TDG data were successfully downloaded. After the data were reviewed in the field, the sondes were reinitialized and redeployed. The water depth at Stn_134.5L was 1.2 m and the sonde housing was fully submerged. At Stn_136.5R, water depth was only 0.7 m, which was sufficient to completely submerge the sonde; however, the top of the housing remained slightly above the water surface.

2.3.5 Station Service – 23–27 October

The October service visit was the last service of the Array prior to winter. New batteries and desiccant packs were installed at Stn_106.8 and Stn_107.1L. At both stations, the inline air reference desiccant and humidity indicators within the battery and RMU housings indicated moderate humidity levels within the housing and that a desiccant change was required. Visual evidence of condensation and corrosion were not evident on the components at either station. The station probe housings were not retrieved and inspected as the TDG probes were functioning effectively at the time of the service. The risk of damaging the TDG probes by exposing them to cold air temperatures (-15°C at the time of the service) was considered greater than the benefit of retrieving the housings to conduct a visual inspection and to clean the probe TDG sensors.

On 23 October, the buoy-based TDG station at Stn_112.5L was replaced with a shore-based TDG station to reduce the risk of damage from river ice over the winter. The shore-based TDG station's probe was deployed at a depth of 3.8 m within the back eddy at the site. On 25 October, the initial TDG readings from the new shore-based station were unrealistically high (i.e., greater than 130 TDG%), which indicated a potential problem with the probe's sensor. On 27 October, the shore-based station's probe (Serial Number 38102) was replaced with a new probe (Serial Number 38103). Once the new probe was installed, the station functioned properly and reported TDG levels that were similar to the TDG levels reported upstream at Stn_106.8R and Stn_107.1L.

The sonde-based TDG stations at Stn_134.5L and Stn_136.5R were downloaded successfully on 26 October. A biofilm had accumulated on the TDG sensors of both stations; however, this biofilm did not appear to affect TDG readings. The TDG sensor membranes were gently cleaned as per the manufacturer's instructions and all TDG data were successfully download. After the data were reviewed, the sondes were reinitialized. During servicing of Stn_134.5L, it appeared that someone had pulled the station nearer to shore by its shoreline cable and the station was found in less than 1 m of water upon arrival. Based on a subsequent review of the station's data, this change likely occurred on 2 September. After 2 September, station periodically dewatered and was exposed to the atmosphere as water levels fluctuated. During these periods of dewatering, the data were not representative and were not included in the analysis. After servicing and data download, Stn_134.5L was redeployed at its original location, further out from shore and at a depth of 2.5 m. At this depth, the sonde housing was fully submerged. To reduce the risk of further tampering, the cable connecting the housing to shore was buried to help conceal the location of the station. Stn_136.5R was downloaded, serviced, and then redeployed at a depth of 1.2 m, which was sufficient to completely submerge the sonde and the housing.

3.0 DATA SUMMARY

Due to the 30 km distance separating the upstream (i.e., Stn_106.6L) and downstream (Stn_136.5R) monitoring stations of the Array, TDG data were examined based on station location either upstream or downstream of the Peace-Pine river confluence at RKm 122.0. Stations upstream of the Pine River confluence recorded TDG levels representative of the Peace River and discharge from the diversion tunnels. Stations downstream of the Peace-Pine confluence were grouped together as they represent conditions downstream of the influence of the Pine River, where TDG could be influenced by dissipation and by dilution from the Pine River. Data summarized include the percentage TDG and water temperature, which are measured by each of the monitoring stations. Discharge was also presented because it is known to be a key driver of TDG downstream of hydroelectric infrastructure. The relationship between TDG and these variables is assessed further using statistical models in Section 4.0.

3.1 Stn_106.8R, Stn_107.1L, and Stn_112.5L

In 2023, flows in the Peace River were passed through two diversion tunnels located on the left downstream bank (see Figure 1). Over the monitoring period from 1 August to 31 December, TDG levels ranged from a low of 94.2 TDG% to a high of 115.2 TDG% at stations located upstream of the Peace-Pine river confluence (Table 2; Figure 8).

The lowest TDG (94.2 TDG%) was recorded at Stn_107.1L at 05:00 on 23 November when Peace River mean hourly discharge was 436 m^3/s, as measured at the Water Survey of Canada's (WSC) Peace Above Pine Hydrometric Station #07FA004), and water temperature was 3.0°C. Stn_106.8R and Stn_112.5L also had low TDG (approximately 95% to 96%) on this date.

The highest TDG (115.2 TDG%) was recorded at Stn_107.1L at 14:00 on 15 September when Peace River discharge was 862 m³/s and water temperature was 12.2°C. High TDG was also recorded at Stn_106.8L (113.0 TDG%) and Stn_112.5L (113.0 TDG%) on 15 September. High TDG levels were also recorded at Stn_106.8R (114.5 TDG%,4 August, 1050.8 m³/s, 11.9°C) and Stn_107.1L (115.1 TDG% 5 August, 888 m³/s, 12.4°C) in early August during higher flow conditions.

Downstream of the Project, TDG differed slightly between the left and right banks and in relation to Peace River discharge. When discharge levels were 500 m³/s or less, TDG recorded on the left bank (Stn_107.1L) was between 3 to 5 TDG% higher than TDG recorded on the right bank (Stn_106.8R). As discharge levels increased to approximately 800 m³/s, the difference in TDG between the left and right banks decreased, with TDG on the left bank (Stn_107.1L) between 2 to 3 TDG% higher than TDG recorded right bank (Stn_106.8R). At discharge levels 1000 m³/s and higher, the pattern reversed, with TDG on the right bank (Stn_106.8R) between 2 to 3 TDG% higher than TDG recorded left bank (Stn_107.1L). The difference in TDG between the left and right banks suggests that the TDG levels of water discharged from the diversion tunnels may differ depending on the amount of discharge from each tunnel. Downstream of the Project, when discharge was less than 1000 m³/s, TDG at Stn_112.5L tended to track with TDG levels recorded on the right downstream bank at Stn_106.8R. However, when discharge was greater than 1000 m³/s, TDG at Stn_112.5L tended to track with TDG levels recorded on the left downstream bank at Stn_107.1L. Dissipation of TDG was not evident at Stn_112.5L compared to upstream TDG levels. Seasonally, TDG produced by a given flow decreased with water temperature, with lower TDG levels recorded after approximately 15 October when water temperature decreased below 11°C.

The percentage of days when TDG was within particularly ranges of values (<100%, 100%-110%, 110%-115%, and >115%) was summarized to understand the relative amount of time when TDG was supersaturated (>100%), and below the cut-off for Low risk of GBD to aquatic life (110%; Fidler and Miller [1997]). TDG was below 110 TDG% for the majority of the 2023 monitoring period at Stn_106.8R (132.6 of 149.6 days; 89%), Stn_107.1L (130.1 of 150.8 days; 86%), and at Stn_112.5L (106.7 of 118.5 days; 90%). The number of days when TDG was between 110 and 115 TDG% was slightly higher at Stn_107.1L (20.5 of 150.8 days; 14%) compared to Stn_106.8R (17.0 of 149.6 days; 11%) and Stn_112.5L (11.8 of 118.5 days; 10%). TDG above 115 TDG% was rarely recorded and was only recorded at Stn_107.1L (0.2 of 150.8 days; <1%; Table 2).

Table 2: The TDG minimum, maximum, and days exceeding various thresholds for Site C TDG Monitoring Array stations situated upstream of the Peace-Pine confluence, 1 August to 31 December 2023.

Station	Total (days)	TDG% min	TDG% max	Days less than 100 TDG%	Days between 100-110 TDG%	Days between 110-115 TDG%	Days greater than 115 TDG%
Stn_106.8R	149.6	95.0	114.5	55.1	77.5	17.0	0.0
Stn_107.1L	150.8	94.2	115.2	57.6	72.5	20.5	0.2
Stn_112.5L	118.5	95.5	113.0	58.0	48.7	11.8	0.0

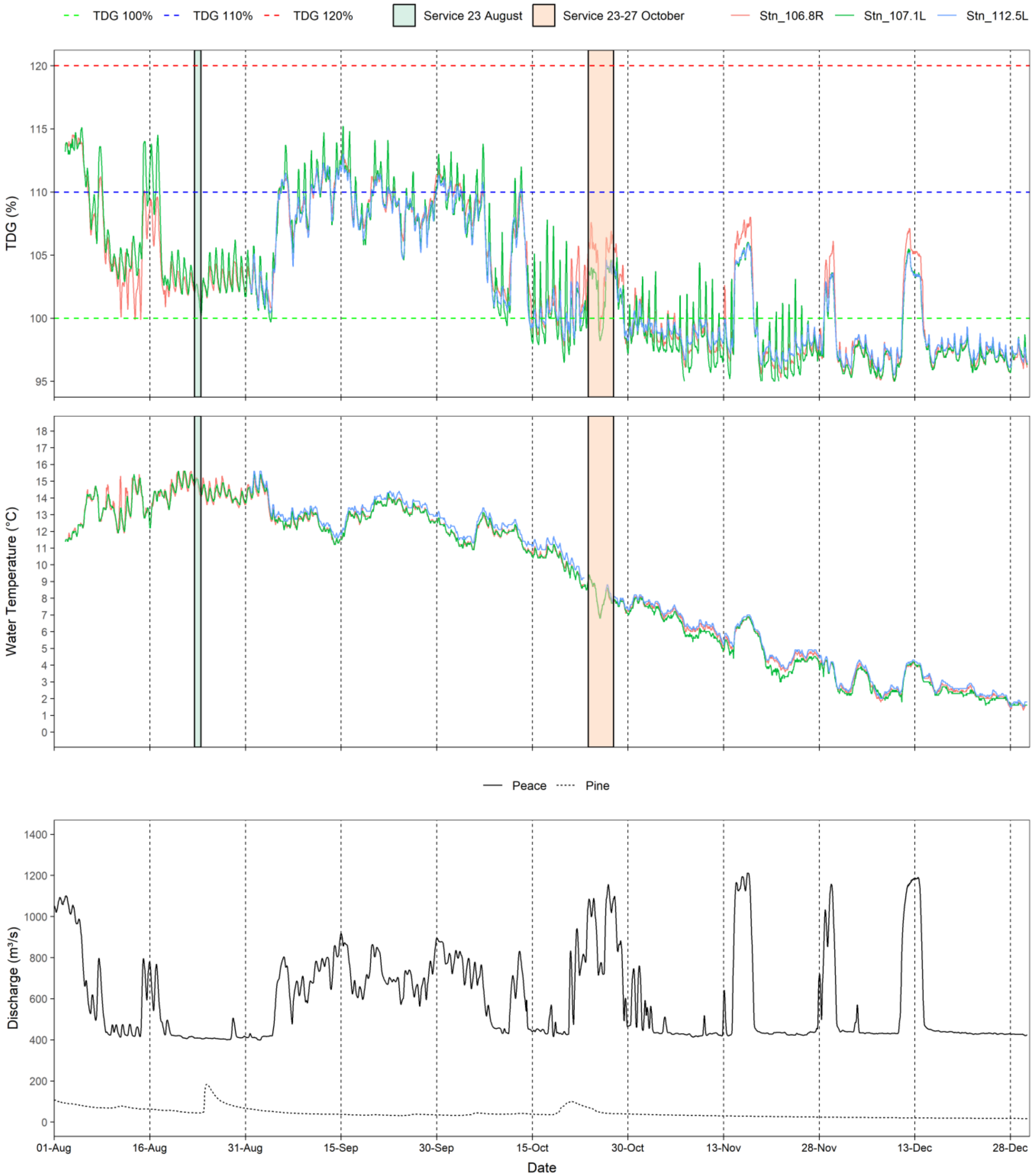

Figure 8: TDG (top panel) and water temperature (middle panel) recorded at Site C TDG Monitoring Array stations upstream of the Peace-Pine confluence (Stn_106.8R, Stn_107.1L, and Stn_112.5L), from 1 August to 31 December 2023. Hourly discharge at the Peace River above Pine River (WSC Station #07FA004) and the Pine River at East Pine hydrometric stations (#07FB001) over the same time period are presented in the bottom panel.

3.2 Stn_134.5L and Stn_136.5R

Downstream of the Peace-Pine confluence, TDG data were available at Stn_134.5L and Stn_136.5R between 2 August and 31 December 2023. Over the monitoring period, TDG recorded by these two stations ranged between a low of 94.3 TDG% and a high of 114.6 TDG% (Table 3; Figure 9).

The lowest TDG (94.3 TDG%) was recorded at Stn_136.5L between 07:00 and 08:00 on 20 November when Peace River mean hourly discharge was 433 m³/s, Pine River discharge was 27 m³/s, and water temperature recorded at the station was 3.8°C. The lowest TDG at Stn_134.5L (94.7 TDG%) was recorded on 11 December during similar flow and temperature conditions.

The highest TDG (114.6 TDG%) was recorded at Stn_134.5L at 15:00 on 5 August when Peace River discharge was 867 m³/s and water temperature was 14.6°C. Similarly, the highest TDG at Stn_136.5R (111.7 TDG%) was recorded on 4 August under similar flow and temperature conditions.

TDG at Stn_134.5L and Stn_136.5R was between 3 and 5 TDG% lower than TDG levels recorded at stations upstream of the Peace-Pine confluence. This reduction in TDG was likely due in part to dilution of Peace River discharge by low TDG water from the Pine River. Dissipation and outgassing of TDG as water transited the 30 km between the upstream and downstream stations also likely contributed to the decline.

Increases and decreases in TDG recorded at both downstream stations generally corresponded to changes in Peace River discharge, with higher TDG recorded during periods of higher Peace River discharge. From 2 August to 2 September, higher TDG was recorded on the left downstream bank than on the right downstream bank. This difference was likely due to incomplete mixing between Peace River and Pine River discharge, with higher TDG water from the Peace River predominantly following the left bank and lower TDG water from the Pine River predominantly following the right bank. A similar pattern was observed at the upstream stations, where higher TDG levels were typically recorded on the left bank than the right bank in August (Figure 8). After Stn_134.5L was tampered with on 2 September and pulled into shallower water (Section 2.3.5), the daily maximum TDG at this station decreased and was more similar to TDG recorded at Sth_136.5R. Both downstream stations exhibited strong diel changes in TDG that were possibly related to diel temperature fluctuations, changes in discharge, photosynthesis, or a combination of three variables. After Stn_134.5L was pulled into shallow water on 2 September, the magnitude of diel changes in TDG recorded at this station were attenuated, which suggests that deployment depth and fluctuating water levels were other factors that affect TDG recordings at both downstream stations. Additional data over a range of discharge levels from the Peace River and Pine River will be required to further assess the relationship between TDG generated by the Project and changes in TDG downstream of the Peace-Pine confluence.

Table 3: The TDG minimum, maximum, and days exceeding various thresholds for Site C TDG Monitoring Array stations downstream of the Peace-Pine confluence, 2 August to 31 December, 2023

Station	Total (days)	TDG% min	TDG% max	Days less than 100 TDG%	Days between 100-110 TDG%	Days between 110-115 TDG%	Days greater than 115 TDG%
Stn_134.5L	136.7	94.7	114.6	46.3	86.3	4.1	0
Stn_136.5R	134.7	94.3	111.7	42.6	90.9	1.2	0

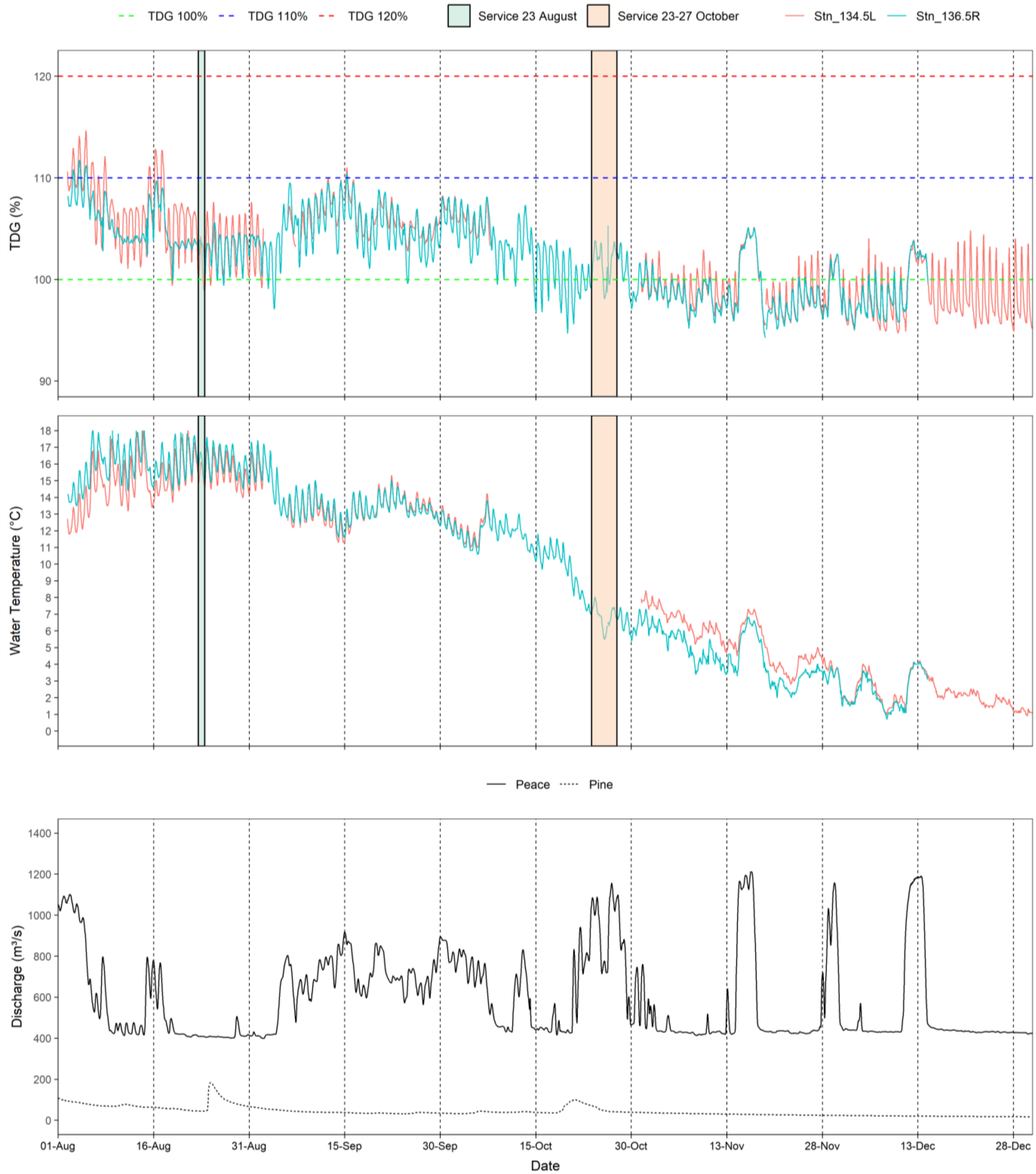

Figure 9: TDG (top panel) and water temperature (middle panel) recorded at Site C TDG Monitoring Array stations downstream of the Peace-Pine confluence (Stn_134.5L and Stn_136.5R), from 2 August to 31 December, 2023. Hourly discharge at the Peace River above Pine River (WSC Station #07FA004) and the Pine River at East Pine hydrometric stations (#07FB001) over the same time period are presented in the bottom panel.

4.0 STATISTICAL ANALYSIS

4.1 Background and Methods

The amount of TDG downstream of the Project could be influenced by numerous factors. Water temperature affects the amount of TDG through several mechanisms, including decreasing solubility of gases that can be dissolved in water at saturation as temperature increases, increased rate of mass transfer between air and water with increasing water temperature, and increased dissipation of supersatured TDG with increasing temperature (Shen et al. 2014; Li et al. 2022). The total discharge, headpond and tailwater elevations, as well as the geometry and other attributes of dam infrastructure and river channel could all affect the amount of TDG downstream of a hydropower dam (Li et al. 2022). Primary productivity, which generates oxygen through photosynthesis, has also been show to increase TDG in some locations (McGrath et al. 2006; Demars et al. 2021). As a preliminary investigation into the factors that affected TDG in the Peace River downstream of the Project, statistical analyses were conducted.

Analyses consisted of linear models to assess which environmental and operational variables affected total dissolved gas downstream of the Project. Data from the two stations closest to the Project (Stn_106.8R and Stn_107.1L) were used in the models. The response variable was the percentage of total dissolved gas. The predictor variables were Peace River discharge (from the Water Survey of Canada's Peace River above Pine River station; Station 07FA004), headpond surface water elevation ('headpond elevation'), water temperature, hour of day, station, and operational period. The operational periods were "T1 Only" (which includes the June 15 to October 13, 2023 period when only Diversion Tunnel 1 was used to pass Peace River flows) and "T1 and T2C" (which includes the October 14 to December 31, 2023 period when Peace River flows were passed through both Tunnel 1 and the converted Diversion Tunnel 2). Discharge and headpond elevation could not be included in the same model because the variables were highly correlated; therefore, separate models was created for discharge and headpond elevation, with each model including all other variables listed above. Based on preliminary visualization of the data, the models included the two-way interactions between discharge/headpond elevation and temperature, operational period and temperature, and operational period and discharge/headpond elevation. As discharge measurements were from approximatley RKm 112, the discharge values were lagged (moved backwards in time) by 45 minutes to correspond to the timing of discharge at Stations Stn_106.8R and Stn_107.1L, based on the approximate travel time for water between these locations. The headpond elevations were from RKm 105 and were led (i.e., moved forward in time) by 30 minutes to correspond to TDG measurements at 106.8R and 107.1L.

Water surface elevation of the Peace River downstream of the Project at the Peace River Construction Bridge (RKm 107) was considered as a potential predictor variable to assess the influence of tailwater elevation; however, this variable could not be included in the models because it had significant periods of missing data and was too highly correlated with Peace River discharge.

To assess potential effects of primary production on TDG, measurements of light and turbidity were considered as predictor variables that could serve as proxies for primary productivity. However, light data were not available for the same period as TDG. Prelminary analyses did not indicate any effect of turbidity, and this variable was correlated with other predictors so it was omitted from analyses. Hour of day, which was included as a categorical variable, may serve as a proxy for light and therefore primary productivity, as well any other diurnal effects that were not accounted for by discharge or water temperature.

Prior to analysis, the data set was reduced to a four-hour interval (i.e., only data from 0:00, 4:00, 8:00, 12:00, 16:00, and 20:00 were used) because initial analyses indicated significant autocorrelation in model residuals that could not adequately be resolved using various time-lag or moving-average error structures to account for temporal autocorrelation. Models were fit using generalized least squares and included a first order, auto-regressive error structure to account for remaining autocorrelation over time at each station. TDG data were available from 3 August to 31 December 2023. Between 3 and 24 August, there were short gaps in the TDG data, which complicated auto-correlation structures that assumed equal time intervals between observations. Therefore, for both stations, only data from 25 August to 31 December 2023 were used in the analysis.

Model checking and diagnostics included standard plots of model residuals, plots of residuals vs. predictor variables, and the variance inflation factor to assess collinearity. Candidate models were compared using Akaike's Information Criterion (AIC). The effect of predictor variables of interest were visualized by plotting model-predicted TDG versus a predictor variable while holding other continous variables at their mean values, hour of day at 12:00, and operational period at "T1 and T2C".

4.2 Results and Discussion

The model that included headpond elevation had a lower AIC value (4,131) than the model including Peace River discharge (4,230), indicating better support by the data for the headpond elevation model. All predictor variables and interactions in the models were statistically significant, except for station (not significant in discharge model) and some of the interaction effects (Table 4). Estimated model coefficients for continuous predictor variables indicated positive effects of discharge, water temperature, and headpond elevation (Table 4). The magnitude and direction of the effects of predictor variables was visualized using plots of TDG predictions versus each predictor, while holding other variables at their mean values (Figures 10 to 14).

Table 4: Statistical significance of predictors of TDG based on likelihood-ratio tests.

Model Including Discharge			Model Including Headpond Elevation		
Predictor Variable	**Chi-squared Statistic**	***P*-value**	**Predictor Variable**	**Chi-squared Statistic**	***P*-value**
Discharge	74.1	<0.0001	Elevation	85.3	<0.0001
Water temperature	37.2	<0.0001	Water temperature	143.4	<0.0001
Period	16.4	0.0001	Period	124.6	<0.0001
Station	3.0	0.09	Station	4.3	0.04
Hour of Day	770.6	<0.0001	Hour of Day	778.8	<0.0001
Discharge by temperature interaction	0.0	>0.9	Elevation by temperature interaction	1.9	0.2
Discharge by period interaction	73.3	<0.0001	Elevation by period interaction	20.8	<0.0001
Temperature by period interaction	4.0	0.045	Temperature by period interaction	1.4	0.2

Table 5: Coefficient estimates from linear models of TDG.

Model Including Discharge			Model Including Headpond Elevation		
Predictor Variable	**Estimate**	**Standard Error**	**Predictor Variable**	**Estimate**	**Standard Error**
Intercept	87.72	1.21	Intercept	-353.62	52.33
Discharge	0.02	0.00	Elevation	1.09	0.13
Water temperature	0.63	0.10	Water temperature	-7.23	5.35
Period (T1 and T2C 2023)	-3.89	0.97	Period (T1 and T2C 2023)	-103.30	22.11
Station (107.1L)	0.13	0.08	Station	0.13	0.07
Hour of Day (4:00)	-0.48	0.05	Hour of Day (4:00)	-0.45	0.04
Hour of Day (8:00)	-0.69	0.05	Hour of Day (8:00)	-0.66	0.05
Hour of Day (12:00)	-0.66	0.05	Hour of Day (12:00)	-0.73	0.05
Hour of Day (16:00)	0.97	0.05	Hour of Day (16:00)	0.87	0.04
Hour of Day (20:00)	1.10	0.05	Hour of Day (20:00)	1.12	0.05
Discharge by temperature interaction	0.00	0.00	Elevation by temperature interaction	0.02	0.01
Discharge by period interaction	0.01	0.00	Elevation by period interaction	0.25	0.05
Temperature by period interaction	0.12	0.06	Temperature by period interaction	0.06	0.06

The relationships between discharge and TDG (Figure 10), and elevation and TDG (Figure 11) were similar, reflecting the high degree of correlation between these two predictor variables. Modeled interactions suggested that the effect of discharge depended on operational period but not water temperature (Figure 12). During the "T1 Only" operational period, there was a predicted increase in TDG of 2.2% for every 100 m^3/s increase in discharge. During the "T1 and T2C" period, there was a predicted increase in TDG of 0.9% for every 100 m^3/s increase in discharge (Figure 10).

The effect of headpond elevation depended on operational period but not on water temperature (Figure 12). The effect of elevation was greater (i.e., steeper slope) during the "T1 Only" operational period than during the "T1 and T2C" operational period. There was a 1.5% increase in TDG for every 1 m increase in elevation during the "T1 Only" operational period and a 1.0% increase in TDG for every 1 m increase in elevation during the "T1 and T2C" operational period (Figure 11).

The interaction between water temperature and operational period was statistical significant (P=0.045) in the discharge model but not in the headpond elevation model (P=0.2; Figure 12). The positive coefficient for this interaction term suggested a greater effect (i.e., steeper slope) of temperature during the "T1 and T2C" operational period than the "T1 Only" operational period (Figure 12). Based on the discharge model, for each 1°C increase in water temperature, there was a 0.5% increase in TDG when discharge was the mean value, operational period was "T1 and T2C", and hour of day was 12:00 (Figure 12).

Predicted mean TDG by hour of day (Figure 13) was greatest at 12:00 (102.1%) and 16:00 (102.2%) and lower at 0:00, 4:00, 8:00, and 20:00 (range: 100.4% to 100.9%), while holding water temperature and discharge at their mean values and period at “T1 and T2C”. Predicted mean TDG was 1.9% greater during the “T1 Only” operational period than during the “T1 and T2C” operational period, while holding water temperature and discharge at their mean values (Figure 14). The model-estimated average difference in TDG between stations was small (0.3%; Figure 14) and not statistically significant in the discharge model (Figure 10). However, the raw data showed that differences between Stn_106.8R and Stn_107.1L ranged between approximately -6% and 4%, in the four-hour interval data.

The models used all available predictor variables hypothesized to potentially influence TDG, filtered data to a four-hour interval, and included an error structure to account for first order autocorrelation. However, model diagnostics indicated some remaining autocorrelation in the model residuals that could not be resolved using alternative model specifications and error structures. The remaining autocorrelation violates the model assumption of independent errors, which can result in underestimates of standard error, confidence intervals, and p-values, although coefficients and predicted mean values may still be unbiased (Bence 1995; Schwarz 2018). For these reasons, conclusions and interpretation of the results should not focus on p-values and confidence intervals as they may be biased (i.e., underestimates of uncertainty), but the results can be used as a preliminary assessment of the factors affecting TDG immediately downstream of the Project.

Overall, the model demonstrated good ability to predict TDG using the available predictor variables, based on fit of the predictions with the observed data. Water temperature was an important predictor of TDG, which was not surprising given the known influence of temperature on the solubility of gases and TDG concentration and dissipation (Weitkamp and Katz 1980; Li et al. 2022). A modelling study of TDG on the Columbia River found that water temperature was the most important predictor of TDG in models that also included variables related to river discharge and water surface elevation (AlOMar et al. 2020). Elevation of the headpond and discharge in the Peace River were strongly correlated with each other and both had large positive effects on TDG; model comparison indicated that headpond elevation was a better predictor than discharge. After accounting for other predictor variables, TDG was greater during the period when one tunnel was operational (“T1 Only”) than when both tunnels were operational (“T1 and T2C”). TDG was greater during midday and afternoon that other times of day, after accounting for other predictors, but it is unknown if this was related primary productivity, or other factors not included in the model that varied diurnally. The model-estimated difference in TDG between the left and right bank stations situated approximately 2 km downstream from the Project was fairly small (0.3%, on average). As the data modeled were from a period prior to reservoir filling, the modeled relationships and predictions of TDG at certain discharges or temperatures may not be applicable to conditions present during reservoir filling or future conditions.

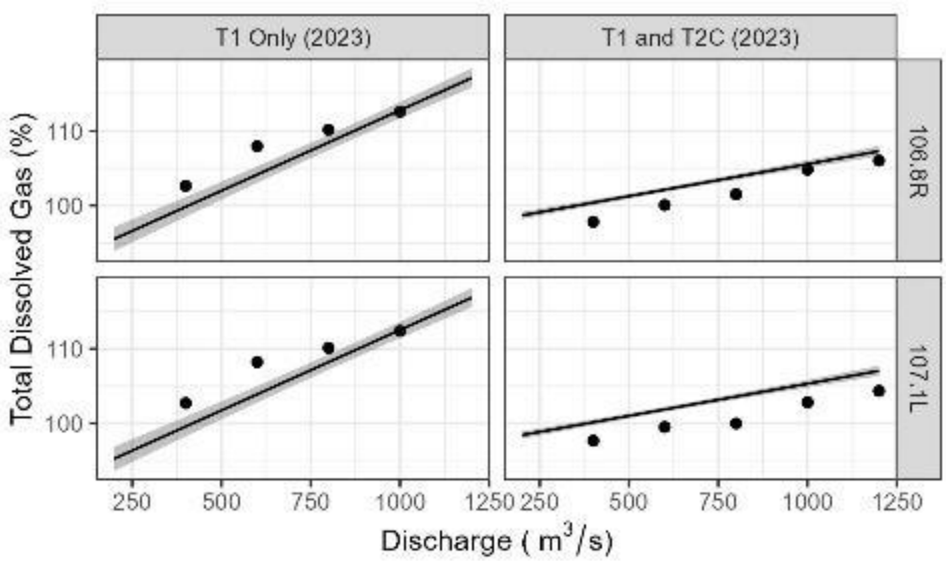

Figure 10: Total dissolved gas by discharge, period, and station. The black lines are model predictions, the grey bands are 95% confidence intervals, and the black points are mean values from the collected data.

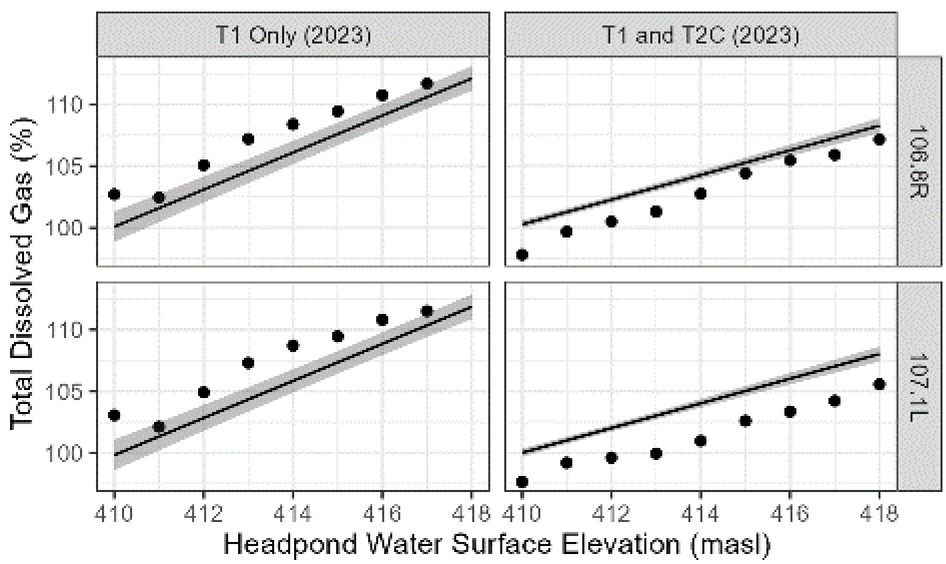

Figure 11: Total dissolved gas by headpond elevation, period, and station. The black lines are model predictions, the grey bands are 95% confidence intervals, and the black points are mean values from the collected data.

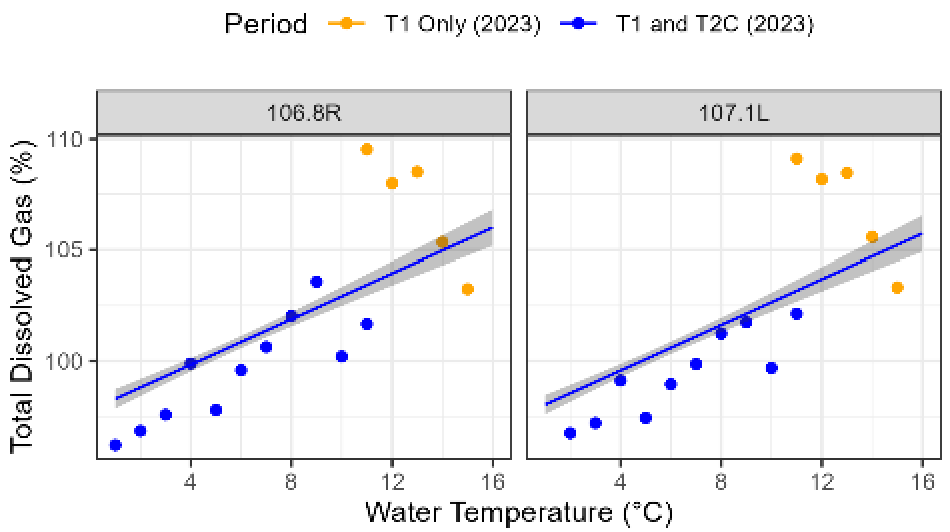

Figure 12: Total dissolved gas by water temperature, period, and station. The blue lines are model predictions, the grey bands are 95% confidence intervals, and coloured points are mean values from the collected data for each operational period.

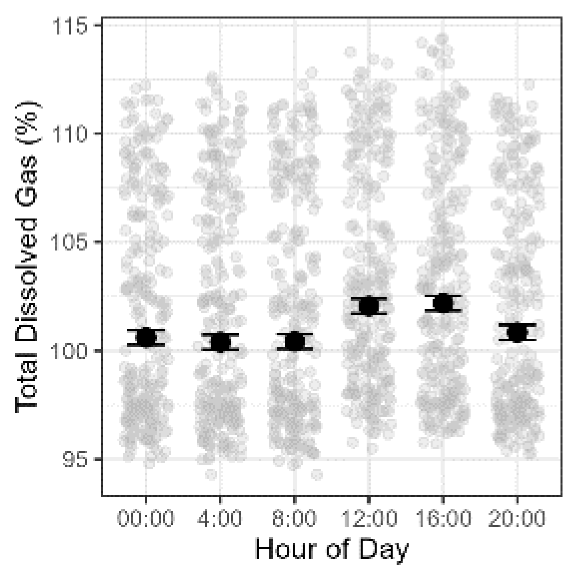

Figure 13: Total dissolved gas by hour of day. The black points with error bars are model predictions with 95% confidence intervals and the grey points are the collected data.

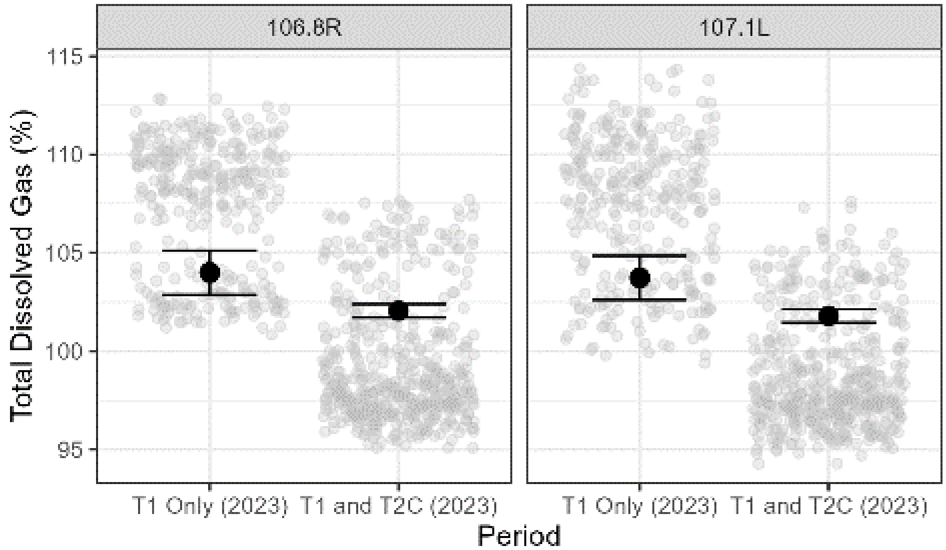

Figure 14: Total dissolved gas by operational period and station. The black points with error bars are the model predictions with 95% confidence intervals and the grey points are the collected data.

5.0 CONCLUSION

In 2023, the array of TDG monitoring stations was installed, and initial maintenance and servicing was conducted to modify the configurations as needed and identify limitations of the monitoring equipment (e.g., sediment build-up and the response times of sensors). Data collected from August to December of 2023 showed that TDG was below 110%, which is a commonly used threshold below which there is low risk to aquatic life, for the majority of monitoring days at the three upstream stations that were closest to the Project (range: 86% to 90% of days) and at the two stations approximately 30 km downstream of the Project (97% and 99% of days). TDG was approximately 3% to 5% lower at the two stations downstream of the Peace-Pine confluence than at the three stations upstream. Statistical analyses of data from the two upstream stations showed that increasing river discharge, increasing headpond water surface elevation, and increasing water temperature all resulted in increases in the percentage of TDG. After accounting for other predictor variables, TDG was greater during the period when one tunnel was operational than when both tunnels were operational (with Tunnel #2 converted), suggesting that the configuration of discharge structures, as well as discharge can influence TDG. Future years of monitoring can be used to assess spatial differences in TDG in the monitoring area as well as the factors affecting TDG during subsequent phases of the Project, such as reservoir filling and operations.

6.0 CLOSURE

We trust that this memo provides the information required at this time. Questions or requests for further detail can be addressed to the undersigned.

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