Thompson Falls Hydroelectric Project
FERC Project No. 1869
Total Dissolved Gas Study – Final Study Report

Prepared by:
NorthWestern Energy
Butte, MT 59701

With Support From:
GEI Consultants, Inc.
Portland, OR 97202

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List of Abbreviations and Acronyms

ARM	Administrative Rules of Montana
cfs	cubic feet per second
DEQ	Montana Department of Environmental Quality
FERC	Federal Energy Regulatory Commission
GBT	gas bubble trauma
ILP	FERC’s Integrated Licensing Process
ISR	Initial Study Report
Licensee	NorthWestern Energy
NorthWestern	NorthWestern Energy
Project	Thompson Falls Hydroelectric Project
TDG	total dissolved gas
TDG Control Plan	Total Dissolved Gas Control Plan
Thompson Falls Project	Thompson Falls Hydroelectric Project
U.S.	United States
USGS	U.S. Geological Survey

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1.0 Introduction

The Thompson Falls Hydroelectric Project (Thompson Falls Project or Project) is located on the Clark Fork River in Sanders County, Montana. Non-federal hydropower projects in the United States (U.S.) are regulated by the Federal Energy Regulatory Commission (FERC) under the authority of the Federal Power Act. The current FERC License expires December 31, 2025. As required by the Federal Power Act and FERC's regulations, on July 1, 2020, NorthWestern Energy (NorthWestern, Licensee) filed a Notice of Intent to relicense the Project using FERC's Integrated Licensing Process (ILP). Concurrently, NorthWestern filed a Pre-Application Document.

The ILP is FERC's default licensing process which evaluates effects of a project based on a nexus to continuing project operations. In general, the purpose of the pre-filing stage of the ILP is to inform Relicensing Participants[1] about relicensing, to identify issues and study needs (based on a project nexus and other established FERC criteria), to conduct those studies per specific FERC requirements which are included in the FERC Study Plan Determination, issued May 10, 2021, and to prepare the Final License Application.

NorthWestern filed the Initial Study Report (ISR) on April 28, 2022, held an ISR meeting on May 5, 2022, and filed an ISR meeting summary on June 9, 2022. Comments on the ISR and meeting summary were filed by FERC staff on July 5, 2022; the U.S. Forest Service on July 6, 2022; the Confederated Salish and Kootenai Tribes on July 7, 2022; the U.S. Fish and Wildlife Service on July 7, 2022; and the Montana Department Fish, Wildlife, and Parks on July 8, 2022. FERC issued a Determination on Requests for Study Modifications for the Thompson Falls Hydroelectric Project on September 1, 2022.

This Total Dissolved Gas (TDG) Final Study Report has been prepared to comply with the requirements of NorthWestern's Revised Study Plan, filed April 12, 2021, as approved in FERC's Study Plan Determination.

1.1 Total Dissolved Gas Study Background

NorthWestern and the prior Licensee monitored TDG in the Clark Fork River most years from 2003 to 2022. These data have helped to inform NorthWestern on the optimal operations scenario to minimize TDG concentrations. The prior Licensee developed a (Total Dissolved Gas Control Plan) TDG Control Plan in 2010 in consultation with the Montana Department of Environmental Quality (DEQ) (PPL 2010**)**. The TDG Control Plan outlines operational

[1] Local, state, and federal governmental agencies, Native American Tribes, local landowners, non-governmental organizations, and other interested parties.

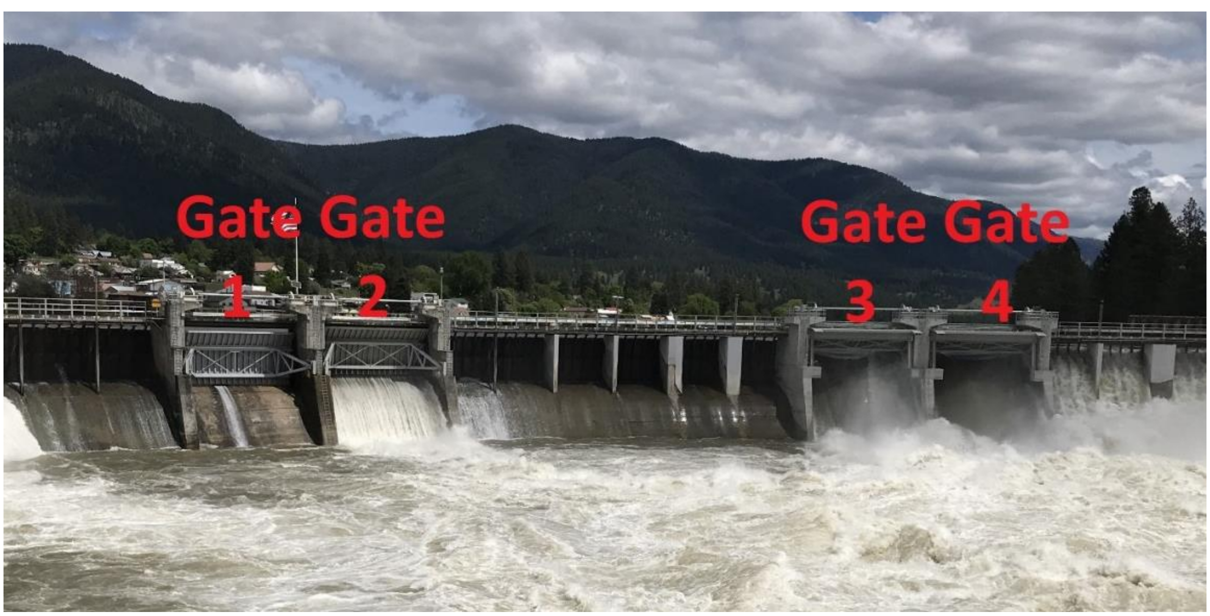
practices used during the spring runoff period to minimize TDG concentrations in the Clark Fork River downstream of the Project. Since 2010, the TDG Control Plan has been implemented annually.

In late 2018, construction was completed on two new radial spill gates, resulting in a total of four radial gates on the Main Channel Dam (**Figure 1-1**). Because these new radial gates are a change from the spill panels that were previously in use, NorthWestern proposed additional TDG monitoring to assess the effect on TDG from the new radial gates. Data collection occurred in 2019, 2020, 2021, and 2022. These data have resulted in a better understanding of TDG concentrations at a wider range of discharge levels.

Water quality standards developed by the DEQ (Circular DEQ-7) (DEQ 2019) set a standard of 110 percent of saturation for TDG. This water quality standard was developed to protect fish from high levels of TDG, which may cause gas bubble trauma (GBT). GBT can cause injury and, in severe cases, death to fish.

Montana's Surface Water Quality Standards and Procedures include language specific to dams. Administrative Rules of Montana (ARM) 17.30.602 defines "naturally occurring" as "conditions or material present from runoff or percolation over which man has no control or from developed land where all reasonable land, soil and water conservation practices have been applied. Conditions resulting from the reasonable operation of dams in existence as of July 1, 1971, are natural." ARM 17.30.636 (1) states that, "…owners and operators of water impoundments that cause conditions harmful to prescribed beneficial uses of state water shall demonstrate to the satisfaction of the department that continued operations will be done in the best practicable manner to minimize harmful effects".

Figure 1-1. View of the Thompson Falls Main Channel Dam Radial Gates Looking Upstream. Gates 3 and 4 were constructed in 2018.



1.2 Goals and Objectives of Study

The goal of this study is to gather data on TDG concentrations upstream and downstream of the Project throughout the spring runoff season to gain a better understanding of TDG concentrations in various discharge scenarios. The main objective is to collect additional information on whether and how the Project's new radial gates affect TDG concentrations downstream of the dams and powerhouses.

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2.0 Methods

2.1 Study Area

Hydrolab instruments (through 2021) and Eureka Manta instruments (2022) were deployed at three locations to capture TDG concentrations above the dam, below the Main Channel Dam at the High Bridge, and downstream of the Project at Birdland Bay Bridge. **Table 2-1** provides the locations of each of these monitoring sites.

Table 2-1: Descriptions and Latitude and Longitude of TDG Monitoring Sites.

Site Description	Latitude	Longitude
Above Dam – Upstream face of the Dry Channel Dam	47.593131	-115.356904
High Bridge – Downstream of the Main Channel Dam	47.590720	-115.354920
Birdland Bay Bridge – Clark Fork River downstream of Project at Birdland Bay Bridge	47.621436	-115.391592

The monitoring locations were chosen to represent the TDG concentrations of incoming water upstream of the Project, TDG concentrations of the spill water downstream of the Main Channel Dam, and TDG concentrations leaving the Project which captures a mixture of water from the powerhouse discharge and the spillway discharge. **Figures 2-1 and 2-2** show the location of the TDG monitoring sites in relation to Project infrastructure.

Figure 2-1. TDG Monitoring Locations

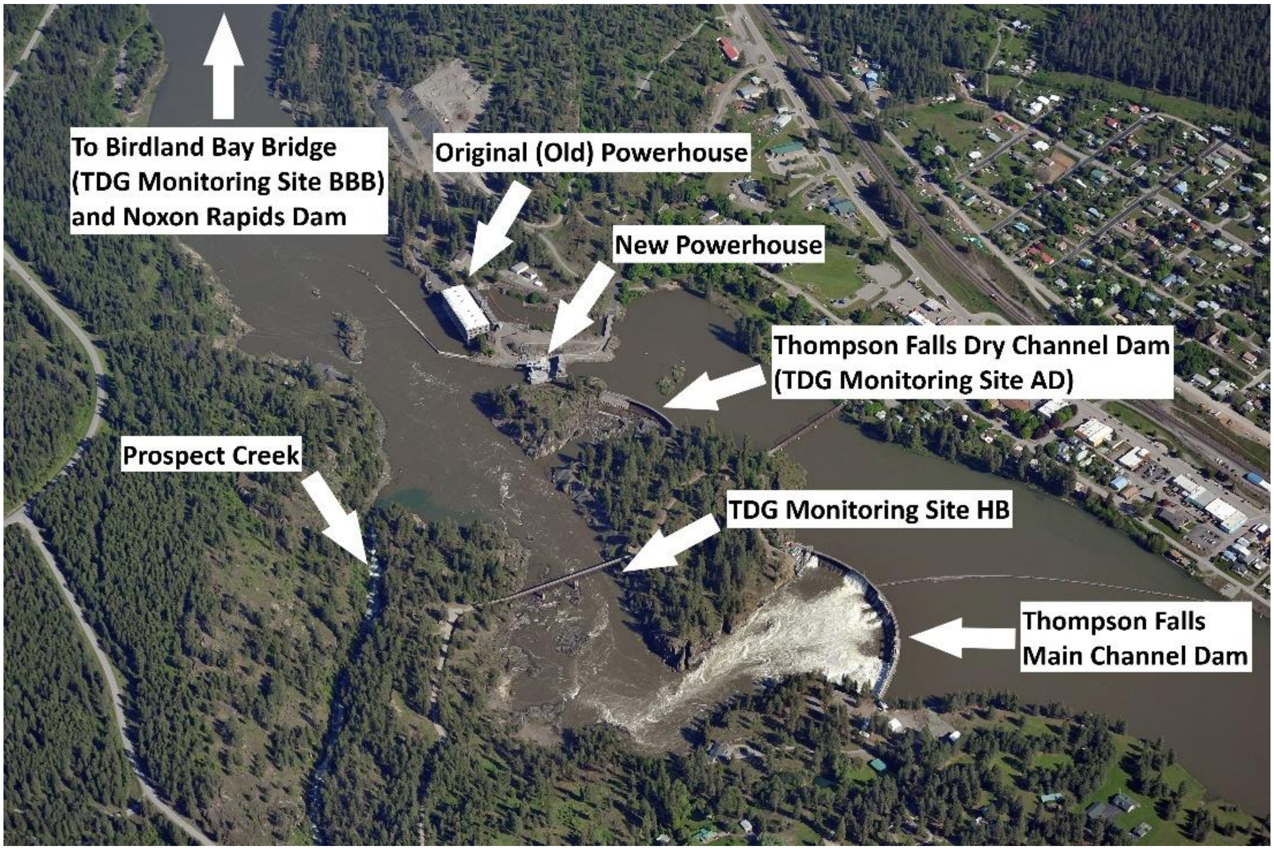
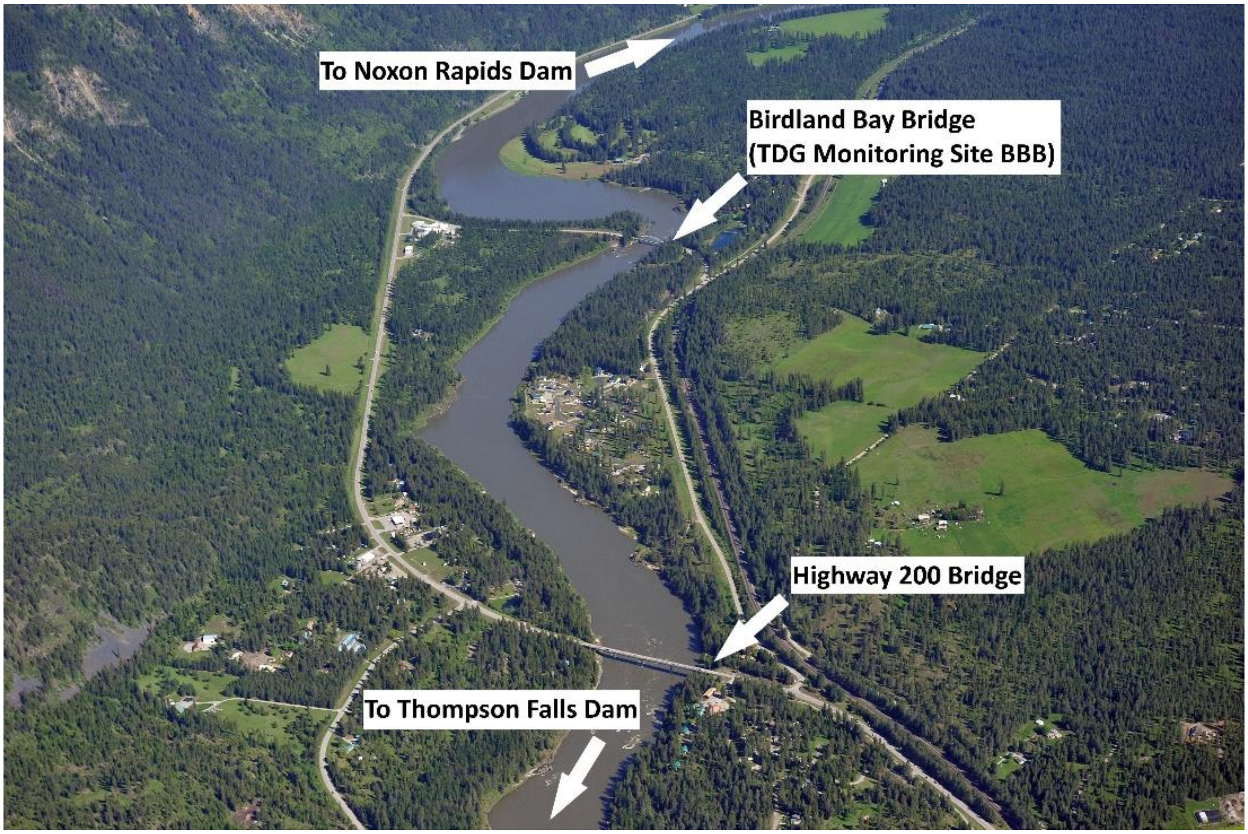


Figure 2-2. TDG Monitoring Locations Downstream of the Thompson Falls Project



2.2 Study Methods

TDG concentrations are highest during spring runoff, so data collection is focused on the early May through early July time period. The first season of the TDG study conducted in 2021 consisted of monitoring TDG concentrations during the spring runoff season (May 12–July 1) at multiple locations around the Project's facilities under different discharge scenarios using Hydrolab instruments. This study used methods that have been used since the TDG Control Plan was put in place in 2010.

In 2022, the same monitoring sites were used, but the monitoring equipment was upgraded from Hydrolab datasondes to Eureka Manta datasondes. The equipment upgrade allows NorthWestern to use newer instrumentation, as Hydrolab does not currently have TDG probes designed for its newer model datasondes.

TDG data were collected throughout the spring runoff season to capture the variability of TDG entrainment in relation to flow rate in the Clark Fork River. In 2022, TDG monitoring was conducted from April 15 to July 25, slightly longer than in 2021. Eureka Manta datasondes were used to measure TDG on 15-minute intervals throughout this monitoring period and were calibrated on a bi-weekly basis to ensure sensor accuracy. On July 21, 2022, Clark Fork River flows had reduced to the point where the entirety of the river flow was passed through the powerhouses. TDG concentrations are highest during the spring runoff season, so data collection ended at the conclusion of the spring runoff, as specified in the Revised Study Plan (NorthWestern 2021).

During the monitoring period, operators of the Project tested various configurations of spill through the Main Channel Dam using different combinations of the four radial gates. Each gate spill configuration was held for approximately 4 hours to allow the downstream TDG levels to stabilize. This methodology was consistent with testing conducted in 2019, 2020, and 2021 and was used to supplement the existing dataset.

2.3 Variances from the FERC-approved Study Plan

There were no variances to study methodology. For the 2022 study season, the aging Hydrolab DS5 instruments were replaced with new Eureka Water Probes Manta instruments. The instrumentation change is an upgrade to a newer technology, which allows for greater instrument reliability and precision. Results between the Hydrolab and Eureka probes are considered comparable, as the quality assurance, quality control, and instrument calibration procedures are the same.

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3.0 Results

In 2022, Clark Fork River flows were above average, and peaked on June 13, 2022, at a flow of 85,000 cubic feet per second (cfs) at the U.S. Geological Survey (USGS) Clark Fork River at Plains stream gage (12389000). The median peak streamflow at the Plains gaging station is 74,750 cfs for the period of record (1912-2021) (USGS 2022). Peak discharge at Thompson Falls Dam occurred on June 13, 2022, and was estimated at 96,567 cfs. This discharge estimate was calculated by adding the discharge at the USGS Clark Fork River at Plains gage to the discharge at the USGS gage at the Thompson River near Thompson Falls (12389500).

The peak concentrations of TDG occurred on June 14th at 124.3 percent TDG directly downstream of the Main Channel Dam, which equated to a peak of 118.5 percent TDG at Birdland Bay Bridge (**Figure 3-1**). The influence of water from the powerhouses reduces the total amount of TDG observed at Birdland Bay Bridge, which is approximately where the upstream end of the Noxon Reservoir pool is located.

Complete results from TDG monitoring in 2019, 2020, 2021, and 2022 are found in **Appendix A**. A summary of the results for different levels of spill are discussed below.

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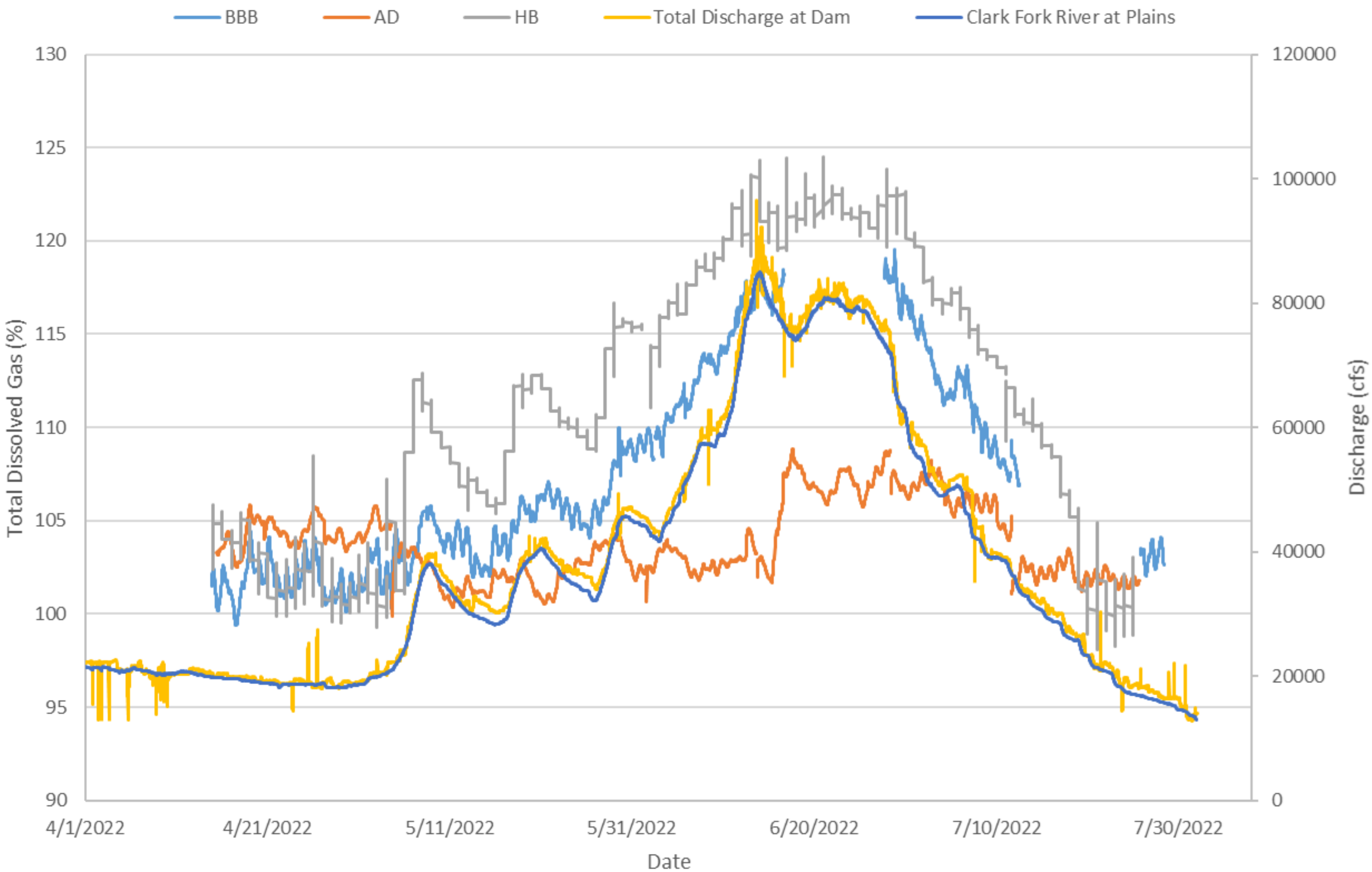
Figure 3-1. TDG and Discharge in the Thompson Falls Project Area by Date, 2022



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During the study period, radial gate testing was conducted to monitor the TDG concentrations in response to different spill configurations. Radial gate testing occurred on the descending limb of the hydrograph at discharges in the 85,000 to 80,000 cfs range and again at the 60,000 to 55,000 cfs range to fill data gaps and supplement data from the previous study seasons. **Table 3-1** shows a summary of the results of gate configuration testing in 2022, as well as a summary of the previous gate configuration testing conducted in 2019, 2020, and 2021.

Table 3-1: Maximum and Minimum TDG by Flow Range at the High Bridge, 2019-2022[2]

Total Flow Range (cfs)	Max TDG at HB (% saturation)	Gate Setting at Max TDG	Min TDG at HB (% saturation)	Gate Settings Min TDG
30,000-35,000	112.5	1 full open, 2 4' open	107.5	4-partially open
40,000-45,000	114.4	1 and 2 open	111.7	1 and 4 open
45,000-50,000	118.8	1 and 4 open	116.2	2 and 4 open
[1]55,000-60,000	121.6	3 and 4 open	119.6	1 and 2 open
[2]55,000-60,000	122.2	1 and 2 open	119.9	2 and 4 open
65,000-70,000	122.7	3 and 4 open	119.8	1 and 3 open
75,000-80,000	123.1	1 and 2 open	121.2	2 and 3 open
80,000-85,000	124.1	3 and 4 open	120.6	1 and 3 open

[1] Partial testing was conducted in 2019
[2] Full testing was conducted in 2022

3.1 TDG Results at 55,000-60,000 cfs Total Flow

The initial round of radial gate testing occurred on May 29, 2019, after the installation of radial gates # 3 and #4. Two gate combinations were tested during this period. At river flows ranging from 55,000 to 60,000 cfs, radial gates #1 and #2 when operated open together entrained less dissolved gas downstream than radial gates #3 and #4 did when operated open together. This testing event was however only a partial test and further testing was needed to fully evaluate TDG in this range of flows.

Due to the need to test other radial gate configurations in this flow range, the test was repeated in 2022 using all potential combinations of radial gate configurations. Although the maximum and minimum TDG saturation levels were similar to those experienced in 2019, the radial gate configurations that produced those maximum and minimum numbers were different in 2022 (*refer to* **Table 3-1**). The 2019 testing in this flow range did not include all possible radial gate configurations, and there is likely some level of environmental variability in the data between the 2019 and 2022 testing events causing this discrepancy. This variability in the data could be caused by a number of outside environmental factors such as incoming upstream TDG

[2] No data are available for the 35,000–40,000 cfs; 50,000–55,000 cfs; 60,000–65,000 cfs; or 70,000–75,000 cfs flow ranges

saturation, water surface elevation below the Main Channel Dam, or simply natural variability in the dataset, which can be commonly observed in datasets with limited sample sizes.

The 2022 testing conducted on June 30 and July 1 showed that operating radial gates #2 and #4 open together entrained the lowest amount of TDG and operating radial gates #1 and #2 open together entrained the highest amount of TDG at river flows between 55,000 and 60,000 cfs.

3.2 TDG Results at 80,000-85,000 cfs Total Flow

Testing on June 15, 16, and 21, 2022 showed that operating radial gates #1 and #3 open together entrained the lowest amount of TDG and operating radial gates #3 and #4 open together entrained the highest amount of TDG at river flows between 80,000 and 85,000 cfs.

4.0 Discussion

In 2022, the peak flow in the Clark Fork River exceeded 2021 levels and was sufficient to test radial gate configurations at flows above 80,000 cfs. The results of the 2022 testing were compiled in a table with the results of the 2019, 2020, and 2021 testing to understand what happens to TDG at various flow conditions and under different radial gate operating scenarios (**Table 4-1**).

Table 4-1: Comparison of the Percentage TDG Entrained Downstream at Various River Flows under Different Radial Gate Operational Scenarios

Total River Flow (cfs)	Lowest %TDG Entrained	Intermediate %TDG Entrained				Highest %TDG Entrained
30,000	4 open	1 open	3 open	N/A	N/A	2 open
35,000	1 and 4 open	2 and 4 open	3 and 4 open	2 and 3 open	N/A	1 and 2 open
40,000-45,000	1 and 4 open	2 and 4 open	1 and 3 open	2 and 3 open	3 and 4 open	1 and 2 open
45,000-50,000	2 and 4 open	2 and 3 open	1 and 2 open	1 and 3 open	N/A	1 and 4 open
[1]55,000-60,000	1 and 2 open	N/A	N/A	N/A	N/A	3 and 4 open
[2]55,000-60,000	2 and 4 open	3 and 4 open	2 and 3 open	1 and 4 open	1 and 3 open	1 and 2 open
65,000-70,000	1 and 3 open	2 and 3 open	1 and 4 open	1 and 2 open	2 and 4 open	3 and 4 open
75,000-80,000	2 and 3 open	1 and 3 open	1 and 4 open	2 and 4 open	3 and 4 open	1 and 2 open
80,000-85,000	1 and 3 open	1 and 2 open	1 and 4 open	2 and 3 open	2 and 4 open	3 and 4 open

Notes:
[1] Testing was conducted in 2019
[2] Testing was conducted in 2022

After testing various radial gate configuration scenarios at flows above 80,000 cfs, the TDG data collected during this study shows that radial gates #1 and #3 tend to entrain the least amount of dissolved gas, while radial gates #3 and #4 appear to entrain the most amount of dissolved gas at these higher flows (*refer to* **Table 4-1**). This data is consistent with previous results measuring TDG at flows above 65,000 cfs.

Additional radial gate testing was performed in the 55,000 to 60,000 cfs range in 2022 to supplement the 2019 dataset. These data displayed a similar range of percent TDG saturation as the 2019 data, but the radial gate combination that entrained the lowest amount of TDG in

2019 entrained the highest amount of TDG in 2022. The discrepancy in the results of these two tests highlights how other outside environmental factors such as incoming upstream percent TDG saturation, differing water surface elevations downstream of the Main Channel Dam, and the overall natural variability of a dataset may mask the actual contributions of TDG from a particular radial gate configuration.

While the radial gate operational scenario that entrained the least amount of TDG differed at various river flows, opening non-adjacent radial gates generally entrains less TDG downstream than opening adjacent radial gates. While opening non-adjacent radial gates during spill operations will most likely reduce the amount of TDG entrained downstream, operation in this manner may not be practical at all times due to the need to flush large woody debris from the trash boom to prevent the debris from building up on the face of the dams.

The buildup of large woody debris on the upstream faces of the Main Channel and Dry Channel dams can lead to situations where the stanchions need to be removed to ensure adequate flow passage and to maintain the structural integrity of the dams. The stanchions hold the dam panels in place which control reservoir elevation. When the stanchions are removed, NorthWestern loses the ability to control reservoir elevation as well as the ability to operate the fish ladder until spring runoff recedes and the dams have been repaired.

In previous instances where the removal of the stanchions has occurred, there was a large increase in the percent of TDG entrained downstream due to uncontrolled releases through the dam. In 2018, which was the last time the stanchions were removed, there was a 5 percent increase in TDG at the High Bridge site following the stanchion removal (NorthWestern 2019). The drastic increase in TDG entrainment from stanchion removal is far more significant than the differences in TDG entrainment from operating adjacent radial gates vs non-adjacent radial gates (**Appendix A**), therefore radial gate operations should be conducted in a way to facilitate passage of debris and minimize the need for emergency stanchion removal.

5.0 Conclusions

NorthWestern's study conclusions are:

- The study found that operating non-adjacent radial gates in combination with each other will generally reduce the amount of TDG entrained in the river downstream under most river conditions. However, operation in this manner may not always be possible due to the need to provide debris passage. The radial gates benefit TDG by limiting the need for emergency stanchion removal.
- A general range of the percent TDG entrained at a particular river flow can be estimated based on the results of this study and previous years of data collection, but other outside environmental factors, such as incoming upstream TDG saturation and the water surface elevation below the Main Channel Dam, may affect the exact value of percent TDG entrainment from year to year at any given flow and radial gate operating combination.

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Appendix A – TDG Data From 2019 – 2022

Date of Test	Gate 1 Status	Gate 2 Status	Gate 3 Status	Gate 4 Status	Approximate Total River Flow (cfs)	Average % TDG During Testing Phase (HB Site)
6/20/2021	Full Open	4’ Open			30,000-35,000	112.5
6/20/2021		Full Open	4’ Open		30,000-35,000	111.9
6/20/2021			Full Open	4’ Open	30,000-35,000	111.0
6/21/2021	3’ Open			Full Open	30,000-35,000	109.4
6/21/2021		3’ Open		Full Open	30,000-35,000	109.6
6/21/2021			3’ Open	Full Open	30,000-35,000	110.3
6/25/2021	8.3’-8.4’ Open				30,000-35,000	107.8
6/25/2021		8.4’-8.0’ Open			30,000-35,000	108.5
6/25/2021			8.0’-7.7’ Open		30,000-35,000	108.1
6/25/2021				7.7’-8.2’ Open	30,000-35,000	107.5
6/16/2021	Open	Open			40,000-45,000	114.4
6/16/2021	Open		Open		40,000-45,000	113.2
6/16/2021	Open			Open	40,000-45,000	111.7
6/17/2021		Open		Open	40,000-45,000	112.5
6/17/2021		Open	Open		40,000-45,000	113.4
6/17/2021			Open	Open	40,000-45,000	113.5
5/23/2019	Open	Open			45,000-50,000	118.0
5/23/2019	Open		Open		45,000-50,000	118.3
5/23/2019	Open			Open	45,000-50,000	118.8
5/23/2019	Open	Open			45,000-50,000	118.7
5/24/2019	Open	Open			45,000-50,000	117.4
5/24/2019		Open	Open		45,000-50,000	116.7
5/24/2019		Open		Open	45,000-50,000	116.2
5/24/2019	Open	Open			45,000-50,000	117.1
5/21/2019	Open	Open			55,000-60,000	119.6
5/21/2019			Open	Open	55,000-60,000	121.6
5/21/2019	Open	Open			55,000-60,000	120.9
6/30/2022	Open	Open			55,000-60,000	122.2
6/30/2022	Open		Open		55,000-60,000	121.7
6/30/2022	Open			Open	55,000-60,000	121.3
6/30/2022		Open	Open		55,000-60,000	120.6
7/1/2022		Open		Open	55,000-60,000	119.9
7/1/2022			Open	Open	55,000-60,000	120.3
5/30/2020	Open	Open			65,000-70,000	120.5
5/30/2020	Open		Open		65,000-70,000	119.8
5/30/2020	Open			Open	65,000-70,000	120.1
5/30/2020		Open		Open	65,000-70,000	120.7
5/30/2020		Open	Open		65,000-70,000	120.1
5/31/2020			Open	Open	65,000-70,000	122.7
6/3/2020	Open	Open			75,000-80,000	123.5
6/3/2020	Open		Open		75,000-80,000	121.5

Date of Test	Gate 1 Status	Gate 2 Status	Gate 3 Status	Gate 4 Status	Approximate Total River Flow (cfs)	Average % TDG During Testing Phase (HB Site)
6/3/2020	Open			Open	75,000-80,000	121.6
6/3/2020		Open		Open	75,000-80,000	123.0
6/3/2020		Open	Open		75,000-80,000	121.2
6/4/2020			Open	Open	75,000-80,000	123.1
6/15/2022	Open	Open			80,000-85,000	121.0
6/15/2022	Open		Open		80,000-85,000	120.6
6/15/2022	Open			Open	80,000-85,000	121.0
6/16/2022		Open	Open		80,000-85,000	121.5
6/16/2022		Open		Open	80,000-85,000	121.6
6/21/2022			Open	Open	80,000-85,000	124.1

Note: HB Site = High Bridge Site