Thompson Falls Hydroelectric Project P-1869

Total Dissolved Gas Control Plan

Final Version - 5/20/2024

NorthWestern Energy

Delivering a Bright Future

Table of Contents

List of Figures

List of Tables

List of Acronyms

AD – Above Dam

ARM – Administrative Rules of Montana

BBB – Birdland Bay Bridge

CFS – Cubic Feet per Second

DEQ – Department of Environmental Quality

FERC – Federal Energy Regulatory Commission

GBT – Gas Bubble Trauma

HB – High Bridge

N/A – Not Applicable

NRCS – Natural Resources Conservation Service

TAC – Technical Advisory Committee

TDG – Total Dissolved Gas

U.S. – United States

USFWS – US Fish and Wildlife Service

USGS – US Geological Survey

Section 1.0 – Introduction and Background

NorthWestern Corporation, a Delaware corporation, d/b/a NorthWestern Energy (NorthWestern or Licensee) prepared this updated Total Dissolved Gas Control Plan (TDG Control Plan) as part of the relicensing of the Thompson Falls Hydroelectric Project, P-1869 (Project). Non-federal hydropower projects in the United States (U.S.) are regulated by Federal Energy Regulatory Commission (FERC) under the authority of the Federal Power Act. A relicensing application was filed with FERC on December 28, 2023, and the current FERC license for the Project expires December 31, 2025.

The Project is located on the Clark Fork River in Sanders County, Montana. Preliminary development of the Thompson Falls Project began in June 1912, and the Project has been operating continuously since 1915.

Total dissolved gas, or TDG, is a measurement of the total concentration of atmospheric gas saturation in water. This can occur naturally from hydraulic features in a waterbody or from human actions on the environment. When water plunges into a pool, air becomes entrained regardless of whether the plunge is a natural waterfall or a dam spillway (Weitkamp and Katz 1980). Supersaturation (TDG in excess of 115 percent of saturation) at hydroelectric projects is primarily caused by water containing gas that was dissolved under a higher than atmospheric pressure.

TDG carrying capacity depends on temperature and ambient pressure. TDG supersaturation is an unstable condition, and if the river channel downstream of a spillway is sufficiently wide and shallow, and with an appreciable enough hydraulic gradient, channel boundary roughness will force flow to “tumble” in a manner where there is increased water surface exposure of ambient air conditions. Where these kinds of open-channel flow conditions occur, TDG levels rapidly drop back to near the stable, 100 percent saturation level. The distance that is required for this to happen varies from site to site. However, if there is a downstream reservoir impounded near the powerhouse tailrace, as is the case at the Project, the normal river gradient is reduced, and the flow regime becomes more stable. Lower reservoir velocities result in less turbulence, and elevated TDG levels often persist above saturation after entering the impoundment. If there are elevated wind levels, enough shear can be created to induce the vertical circulation necessary to reduce TDG levels. Otherwise, the elevated reservoir TDG levels wane slowly by delayed replenishment from lower level TDG inflows.

In Montana, the Montana Department of Environmental Quality (DEQ) has set the water quality standard for TDG at 110 percent of saturation (DEQ 2019). The 110 percent of saturation water quality standard was developed to protect fish from high levels of TDG, which may cause gas bubble trauma (GBT), a condition that affects many aquatic organisms residing in fresh or marine waters which are supersaturated with atmospheric gases. 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."

The Project was constructed in 1915 and built on a natural river falls. Due to the age of the Project, no data on TDG during the pre-Project time period are available. However, the natural waterfalls likely elevated TDG in the Clark Fork River prior to the construction of the Project. NorthWestern and the prior Licensee monitored TDG in the Clark Fork River most years from 2003 to 2023. These data have helped to inform the optimal operations scenario to minimize TDG concentrations. The prior Licensee developed a TDG Control Plan in 2010 in consultation with the DEQ (PPL Montana 2010). The TDG Control Plan outlines operational practices used during the annual 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. 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 through 2023, and these data have resulted in a better understanding of TDG concentrations at a wide range of discharge levels.

This updated TDG Control Plan incorporates the data collected from 2019-2023, and outlines the plan of spill operations to be used under the new License, when issued by FERC. The TDG Control Plan was developed in consultation with the Montana DEQ, and satisfies ARM 17.30.636 (1), which provides 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."

Section 2.0 – Existing Data

This section outlines available data related to the management of TDG at the Project.

Section 2.1 – Hydrology Data

Streamflow in the Clark Fork River is measured by the US Geological Survey (USGS) at a stream gaging station near Plains, MT, approximately 30 miles upstream of the Project. There is only one tributary with appreciable flow between the Plains stream gaging station and the Project, the Thompson River. The USGS also maintains a stream gaging station on the Thompson River near the mouth. The Thompson River contributes, on average, 2.0 percent of the flow in the Clark Fork River with a range of 0.7 percent up to 5.4 percent (USGS 2023). Flow statistics were derived by combining the USGS gage on the Clark Fork River at Plains, Montana (USGS gage 12389000) with the USGS gage on the Thompson River near Thompson Falls, Montana (USGS gage 12389500), to calculate streamflow in the Clark Fork River at the Project (**Figure 2-1**) (USGS 2023).

Mean daily streamflow data were recorded at the USGS stream gage on the Clark Fork River at Plains from October 1, 1910, to present. The Thompson River near Thompson Falls flow data were recorded from March 1 to September 29, 1911, and from April 1, 1956, to present. To ensure that the hydrograph is representative of current conditions, **Figure 2-1** represents the minimum, maximum, median, and mean daily flows from April 1, 1956 to 2022. This period of record allows complete datasets for both USGS gages (Clark Fork River at Plains and Thompson River near Thompson Falls) to be analyzed and provides representative data of upstream flows since the construction of upstream dams on the Flathead River. The ascending limb of the hydrograph begins between mid- and late March, peaks between late May and mid-June, and descends to base flow levels around mid-August (**Figure 2-1**).

A summary of the minimum, maximum, and mean daily streamflow from the Clark Fork River at Plains and Thompson River near Thompson Falls gages combined for the most recent 5-year period (2018-2022) appears in **Table 2-1**. Minimum daily streamflow showed little variation, while both mean and maximum daily streamflow showed substantial variation. Mean daily flows were greater in 2018 and 2022 compared to the long-term average. Mean daily streamflow in recent years ranged from 16,481 cfs (2021) to 25,467 cfs (2018) and maximum daily streamflow ranged from 59,229 cfs (2021) to 104,475 cfs (2018).

Figure 2-1. Thompson Falls Project daily minimum, maximum, median, and mean streamflow, 1956-2022. USGS stream gage stations 12389000 and 12389500

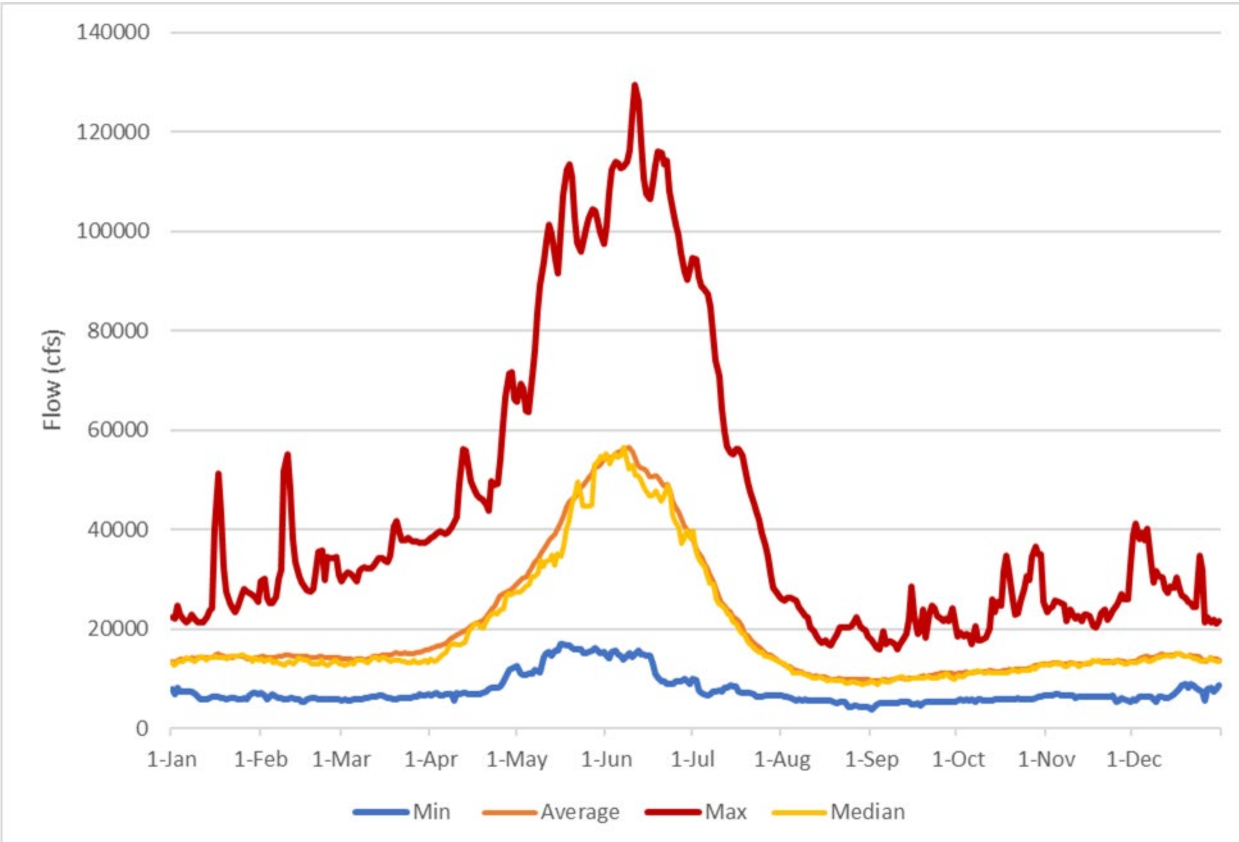


Table 2-1. Summary of Thompson Falls Project daily minimum, maximum, median, and mean streamflow for the water years 2018-2022 and the historic record, 1956-2022. USGS stream gage stations 12389000 and 12389500

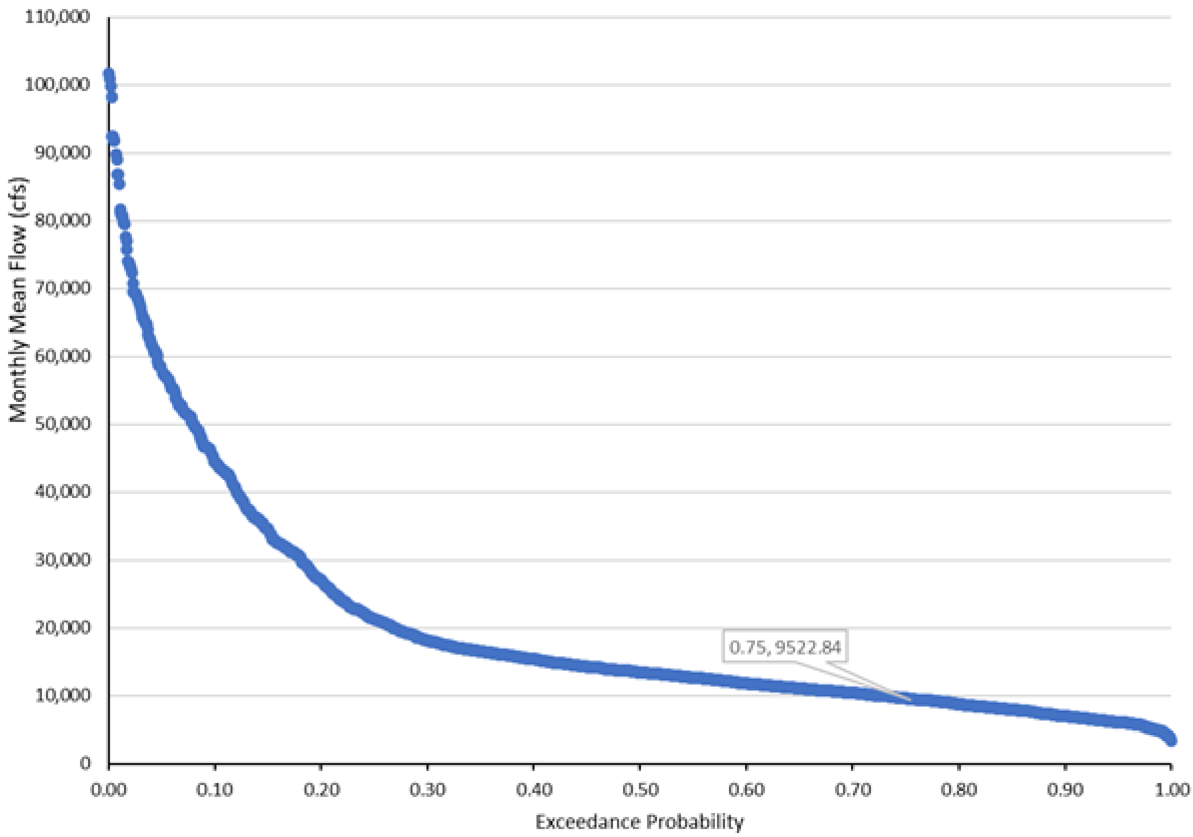
Water Year	Minimum Daily Streamflow (cfs)	Mean Daily Streamflow (cfs)	Median Daily Streamflow	Maximum Daily Streamflow (cfs)
2018	7,895	25,467	16,182	104,475
2019	6,925	16,910	12,088	69,169
2020	7,577	19,712	12,039	79,778
2021	7,164	16,481	12,785	59,229
2022	6,685	20,880	15,662	84,312
1956-2022	**3,806** (1958)	**20,067**	**14,426**	**129,510** (1964)

The maximum daily streamflow for the period of record was 129,510 cfs on June 11, 1964, and the minimum daily streamflow for the period of record was 3,806 cfs on September 1, 1958 (USGS 2023). The average daily streamflow from 1956 to present was calculated from the combined streamflow data of the two recorded USGS gage data to be 20,067 cfs. September has the lowest mean and median daily flows, and June has the highest (**Table 2-2**). The monthly flow duration curve data, shown in **Figure 2-2**, is from the USGS stream gages on Clark Fork River at Plains, Montana (USGS gage 12389000) and Thompson River near Thompson Falls (USGS gage 12389500) combined (USGS 2023).

Table 2-2. Summary of Thompson Falls Project daily minimum, maximum, median, and mean streamflow by month, 1956-2022. USGS stream gage stations 12389000 and 12389500

Month	Minimum Daily Streamflow (cfs)	Median Daily Streamflow (cfs)	Mean Daily Streamflow (cfs)	Maximum Daily Streamflow (cfs)
January	5,688	14,108	14,154	51,130
February	5,216	13,285	14,328	55,170
March	5,607	13,515	14,599	41,780
April	5,435	19,595	21,605	71,650
May	10,632	37,010	41,996	113,450
June	8,771	47,838	50,633	129,510
July	6,257	19,643	23,118	94,590
August	4,141	10,112	10,592	26,301
September	3,806	9,859	10,276	28,534
October	5,179	11,386	11,735	36,439
November	5,295	13,083	13,222	32,980
December	5,295	14,001	14,379	41,140
1956-2022	**3,806** (1958)	**14,427**	**20,067**	**129,510** (1964)

Figure 2-2. Monthly flow duration curve of the Clark Fork River at the Thompson Falls Project from 1911-2023. USGS stream gage stations 12389000 and 12389500



Section 2.2 – Project Operations Data

The Project contains two powerhouses and two dams, which work in conjunction to regulate downstream flow to the Clark Fork River. The total flow capacity of the two powerhouses at Thompson Falls is approximately 23,320 cfs. River flow in excess of this amount is routed over the spillways of the Main Channel and Dry Channel Dams. Each dam is comprised of multiple spill bays, with each bay containing six dam board panels. On the Main Channel Dam, there are 30 spill bays and four radial gates (**Figure 2-3**). The Dry Channel Dam contains 12 spill bays (**Figure 2-4**). Spill is routed through the spill bays by either manually removing dam board panels or opening the radial gates. Each spill panel can pass approximately 235 cfs, and each radial gate can pass approximately 11,000 cfs.

Typically, spill begins in late April, peaks in early June, and ends in mid-July. Additional flow is passed downstream of the Main Channel Dam Spillway during the fish passage season (March – October) to enhance operation of the upstream fish passage facility and to provide fish attraction flow. The minimum flow downstream of the Project is 6,000 cfs or inflows to the reservoir, whichever is less. This value was established under the current FERC license for the Project.

Figure 2-3. Spill bays and radial gates of the Main Channel Dam

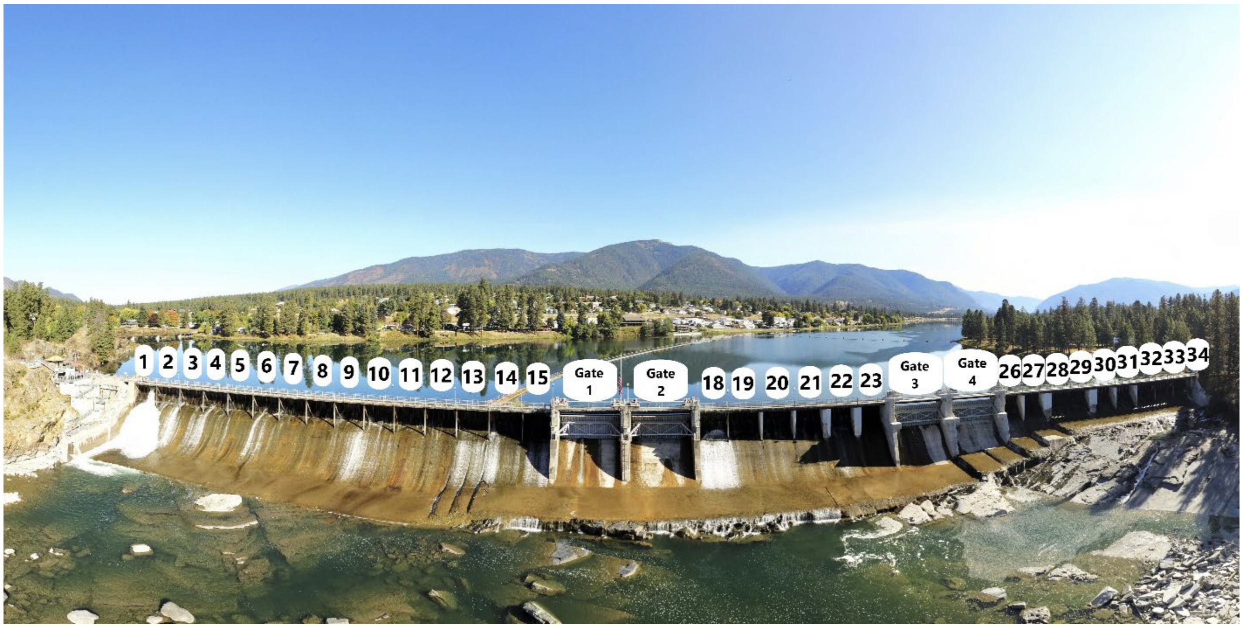


Figure 2-4. Spill bays of the Dry Channel Dam

Section 2.3 – Total Dissolved Gas (TDG) Data

NorthWestern and the prior licensee monitored TDG in the Clark Fork River most years from 2003 to 2023. These data have helped to inform the optimal operational configurations to minimize TDG concentrations downstream. The prior Licensee developed a TDG Control Plan in 2010 in consultation with the DEQ (PPL Montana 2010). The TDG Control Plan outlines operational 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. 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 from 2019-2023, and these data have resulted in a better understanding of TDG concentrations at a wider range of discharge levels.

TDG monitoring at the Project is normally conducted in years where the most probable (50 percent) April 1 Natural Resources Conservation Service (NRCS) runoff forecast for the U.S. Geological Survey (USGS) Clark Fork River near Plains, Montana stream gage (12389000) is at or above 125 percent. This trigger value was agreed upon in 2013 by NorthWestern, DEQ, the US Fish and Wildlife Service (USFWS), and the Thompson Falls Fisheries Technical Advisory Committee (TAC). In years where the April 1 trigger value has been met, NorthWestern monitors TDG throughout the spring runoff season (April-July) at the three established monitoring sites identified in **Section 2.3.1**.

Section 2.3.1 – TDG Monitoring Sites

Water quality sondes are deployed at three locations to monitor TDG concentrations: above the dams, below the Main Channel Dam at the High Bridge, and downstream of the Project at Birdland Bay Bridge. **Table 2-3** provides the details and locations of each of these monitoring sites.

Table 2-3. Location and description of TDG monitoring sites

Site Name	Site Description	Latitude	Longitude
Site AD	Above Dam – Upstream of the Main Channel Dam	47.591912	-115.352619
Site HB	High Bridge – Downstream of the Main Channel Dam	47.590720	-115.354920
Site BBB	Birdland Bay Bridge – Clark Fork River downstream of Project at Birdland Bay Bridge	47.621619	-115.392088

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 2-5 and 2-6** show the location of the TDG monitoring sites in relation to Project infrastructure.

Each TDG monitoring site consists of a stilling well which houses a water quality sonde that collects in-situ measurements at pre-programmed intervals. The data collected helps to generate a continuous dataset for the entire monitoring season, which can be cross-referenced to streamflow values and operational changes at the Project. The sondes are calibrated once every two to three weeks to ensure that the sensors are operating correctly.

Figure 2-5. TDG monitoring locations around the Project infrastructure

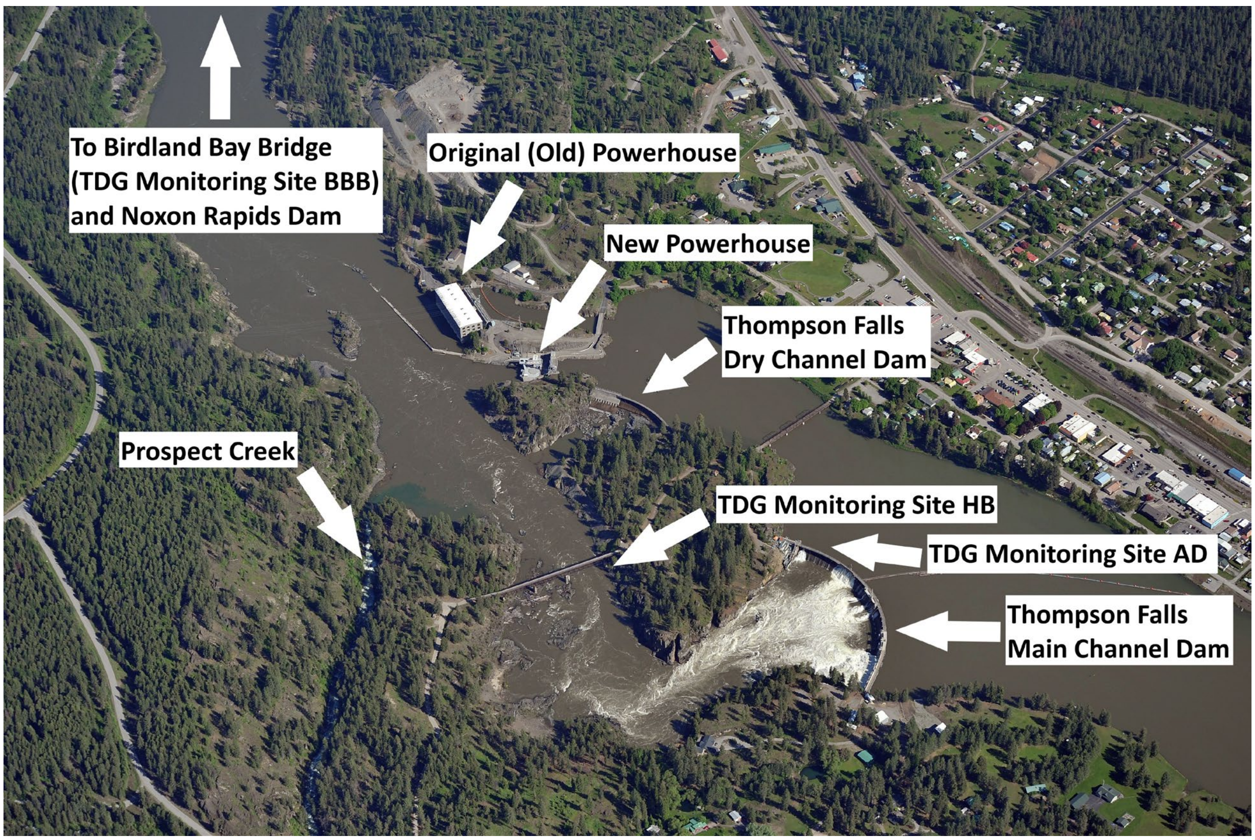
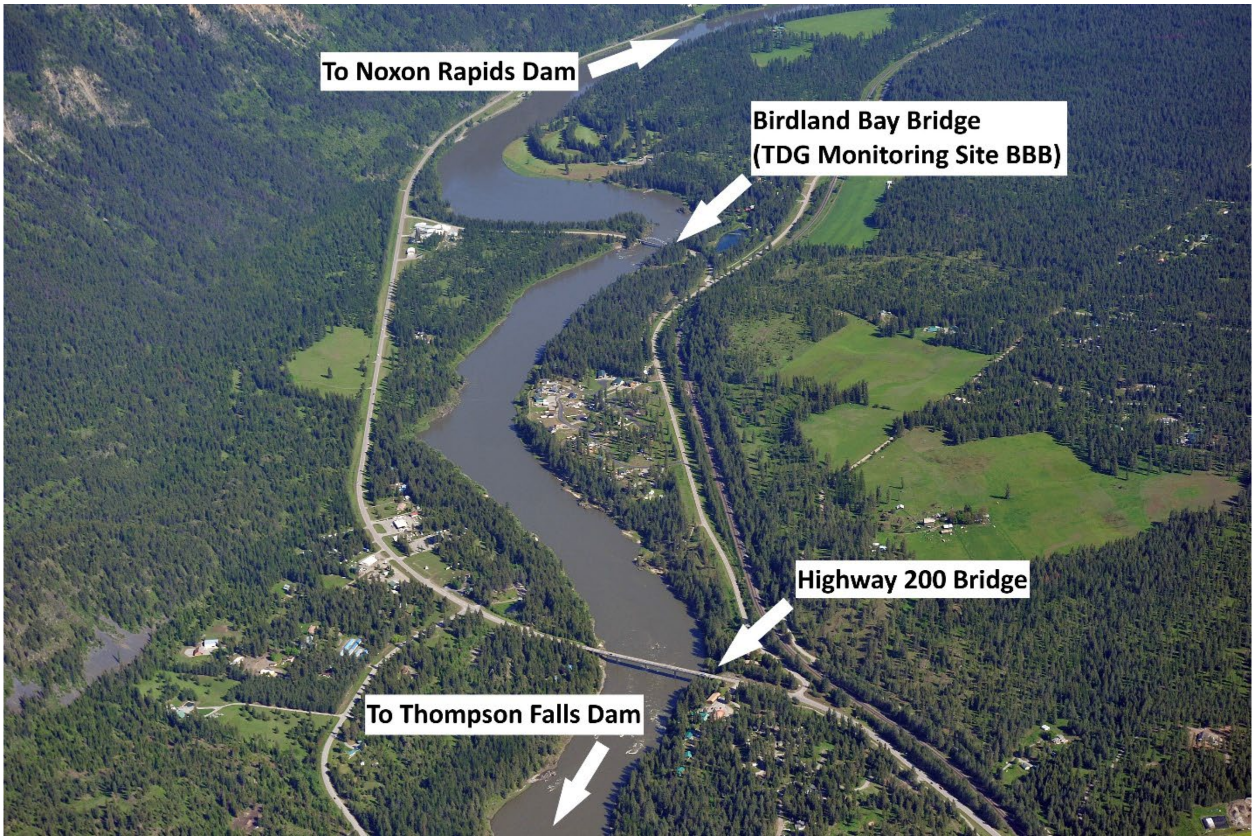


Figure 2-6. TDG Monitoring locations downstream of the Project



Section 2.3.2 – TDG Monitoring Results

Annual TDG Data

For the five years in which all four radial gates were in operation (2019-2023), TDG data were collected annually to help characterize the range of conditions throughout the spill season. **Figures 2-7, 2-8, and 2-9** show the TDG values that were measured at the Above Dam, High Bridge, and Birdland Bay Bridge monitoring sites respectively for the 2019-2023 monitoring periods.

TDG concentrations are lowest at the Above Dam site (**Figure 2-7**), and increase below the Main Channel Dam at the High Bridge site during the spill season (**Figure 2-8**). Water that passes through the two powerhouses contains lower concentrations of TDG, and mixes with the higher TDG water from the Main and Dry Channel dam spillways to lower the TDG concentrations being passed downstream. The furthest downstream monitoring site, Birdland Bay Bridge, effectively characterizes the TDG concentrations downstream of the Project (**Figure 2-9**). **Table 2-4** contains the mean percent TDG measured at the Birdland Bay Bridge site for all years in the monitoring record (2003-2023) for a given streamflow.

Figure 2-7. TDG measurements at the Above Dam monitoring site, 2019-2023

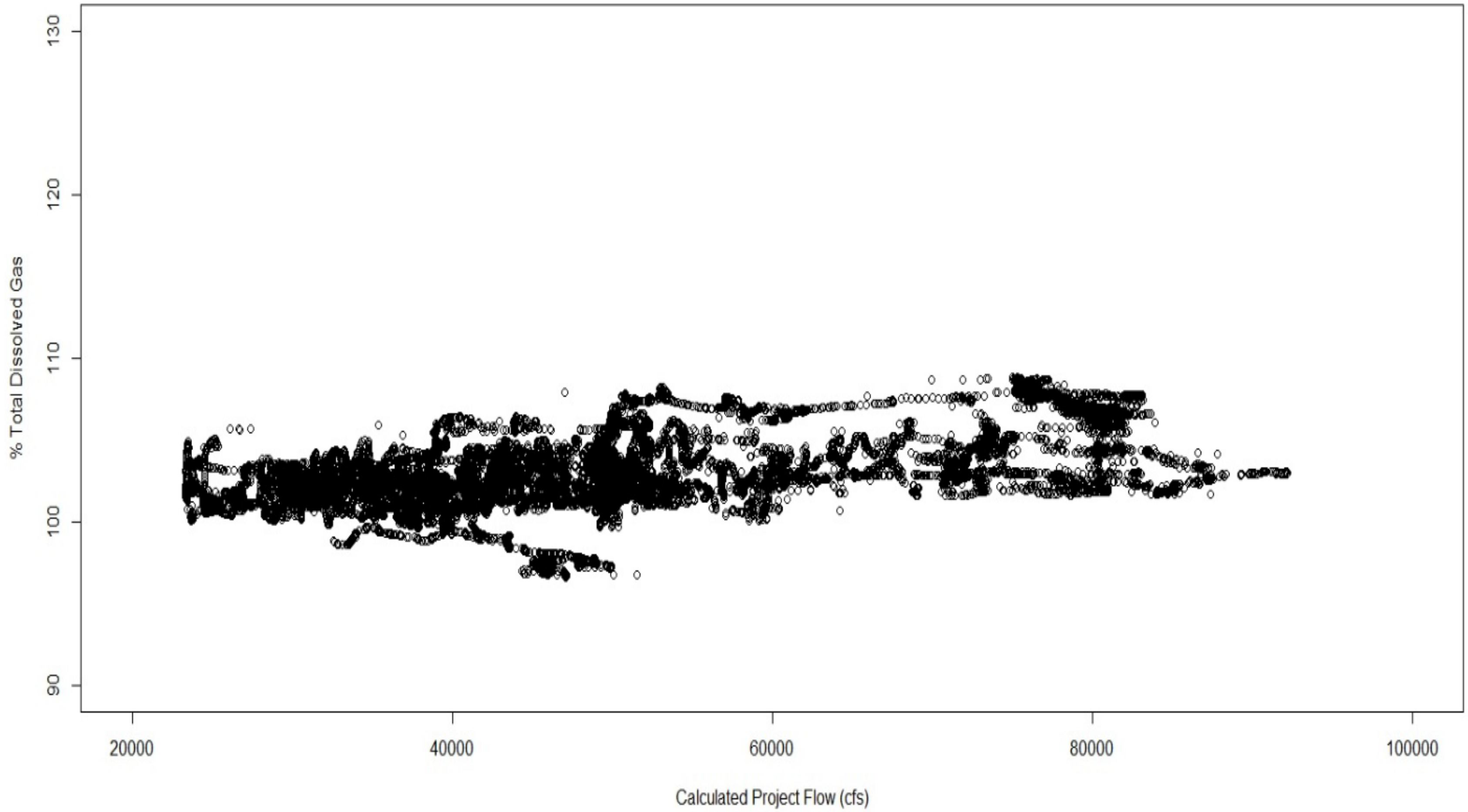


Figure 2-8. TDG measurements at the High Bridge monitoring site, 2019-2023

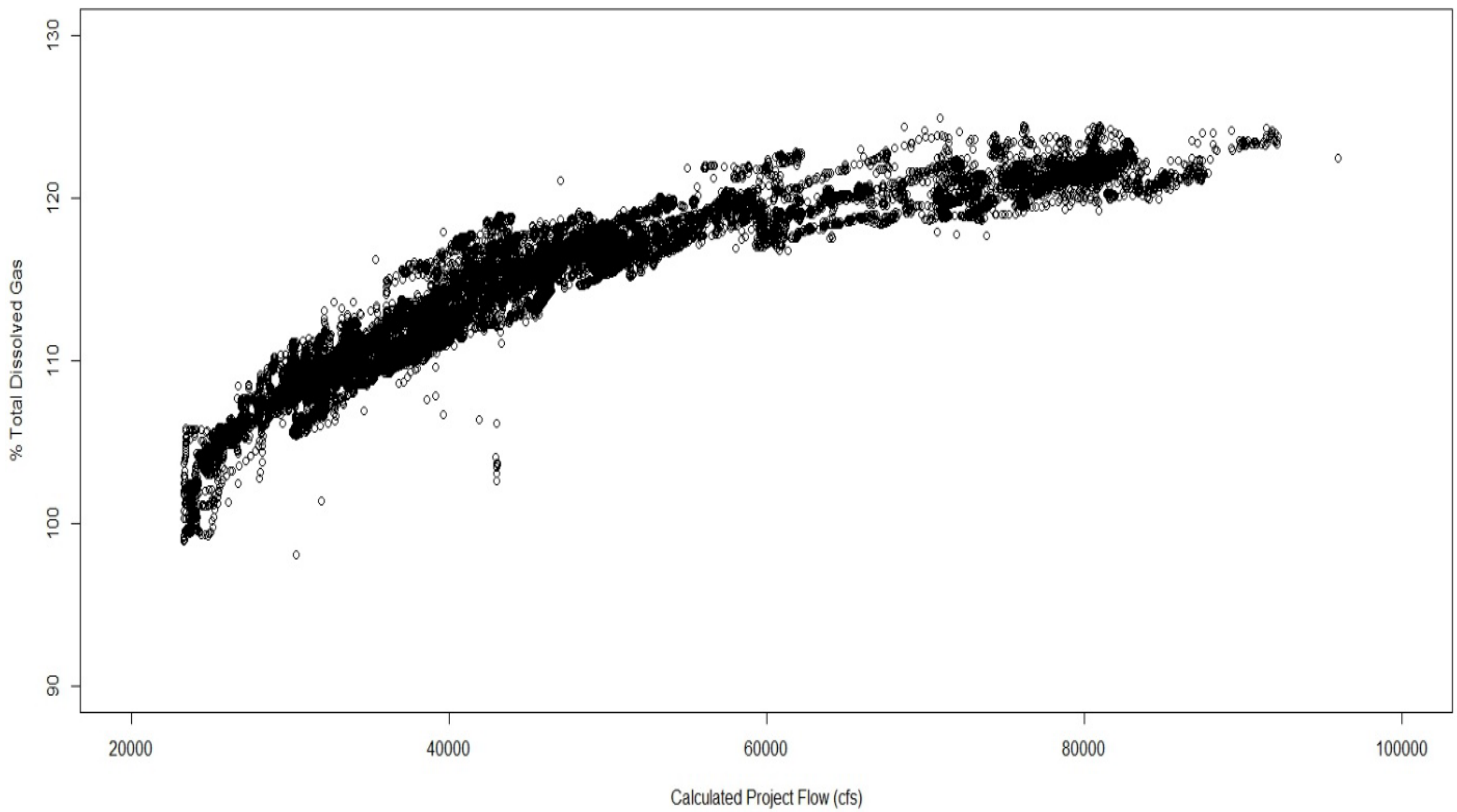


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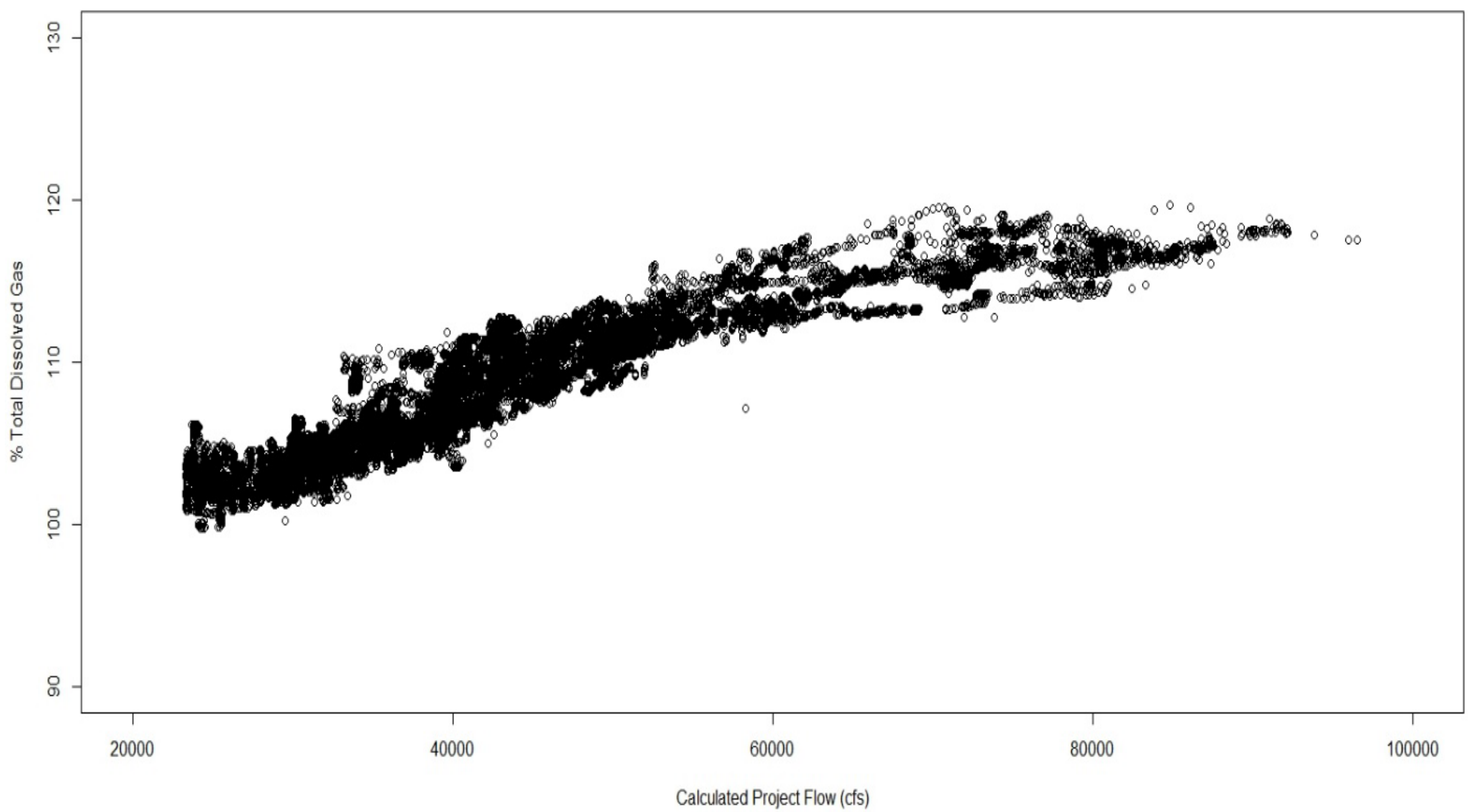
Figure 2-9. TDG measurements at the Birdland Bay Bridge monitoring site, 2019-2023



TDG upstream of the Thompson Falls Project at the Above Dam site, is generally between 100 and 108 percent of saturation regardless of river flow (**Figure 2-7**). TDG measurements collected above the Project and below the powerhouses in 2003 found that TDG in the powerhouse tailrace was generally 1 to 2 percent lower than TDG upstream of the powerhouse (PPL Montana 2010). Therefore, passing flow through the powerhouses results in slight de-gassing of the flow. For this reason, during the time periods when the spillways are not in use, TDG as measured at the Birdland Bay Bridge is generally equal to or slightly less than the TDG measured above the dams (PPL Montana 2010). While the levels of TDG at a particular streamflow varies from year to year, as shown in **Table 2-4**, there does not appear to be a pattern of changing TDG over time.

During peak discharge time periods, when total river flow exceeds 60,000 cfs, TDG exceeds 120 percent at the High Bridge monitoring site, which is downstream of the Main Channel Dam but upstream of the powerhouses' tailrace channels. Higher flows create higher levels of TDG, up to a point, though the relationship between flow and TDG is non-linear. At the highest levels of discharge, TDG at sites downstream of the Project still increases with increasing discharge, but at a much slower rate (**Figures 2-8 and 2-9**). At very high levels of discharge, the tailwater elevation downstream of the Main Channel Dam spillway and natural falls rises enough to create a backwater area near the falls, causing a reduced plunging action into the deep pool below the falls. This reduced plunging action slows the rate at which TDG is entrained downstream.

Table 2-4: Mean TDG (%) recorded over a range of discharge at the Birdland Bay Bridge on the Clark Fork River, 2003-2023

	Total Flow (in thousand cfs)									
Year	**>23, <30**	**>30, <40**	**>40, <50**	**>50, <60**	**>60, <70**	**>70, <80**	**>80, <90**	**>90, <10**	**>100, <110**	**>110, <120**
	Mean Percent Total Dissolved Gas									
2003	102.1	104.7	109.5	111.0	112.9	113.2	N/A	N/A	N/A	N/A
2004	103.5	105.0	107.5	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2005	103.6	107.1	110.4	112.7	114.1	114.0	N/A	N/A	N/A	N/A
2006	103.6	106.7	110.6	114.3	115.7	115.7	N/A	N/A	N/A	N/A
2007	102.5	105.2	109.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2008	102.2	105.6	110.6	114.9	116.0	115.9	N/A	N/A	N/A	N/A
2009	102.6	105.2	109.2	113.0	113.1	N/A	N/A	N/A	N/A	N/A
2010	102.0	106.6	110.9	111.6	N/A	N/A	N/A	N/A	N/A	N/A
2011	102.9	105.8	108.1	111.0	113.5	116.0	116.8	119.7	120.6	119.9
2012	102.3	104.4	108.8	111.2	113.0	112.7	112.5	N/A	N/A	N/A
2014	102.7	104.7	108.6	111.5	114.8	115.4	116.2	N/A	N/A	N/A
2017	103.0	105.2	108.7	113.9	115.2	115.6	116.6	N/A	N/A	N/A
2018	104.0	106.8	110.1	113.3	112.5	115.0	115.7	N/A	N/A	N/A
2019	102.5	104.6	110.5	112.9	113.2	N/A	N/A	N/A	N/A	N/A
2020	102.5	105.5	109.1	112.0	114.3	115.8	116.1	N/A	N/A	N/A
2021	102.9	105.1	108.7	111.8	N/A	N/A	N/A	N/A	N/A	N/A
2022	102.6	105.1	108.9	113.0	115.5	117.5	117.0	118.1	N/A	N/A

Total Flow (in thousand cfs)										
Year	**>23, <30**	**>30, <40**	**>40, <50**	**>50, <60**	**>60, <70**	**>70, <80**	**>80, <90**	**>90, <10**	**>100, <110**	**>110, <120**
Mean Percent Total Dissolved Gas										
2023	103.2	105.6	110.5	112.7	N/A	N/A	N/A	N/A	N/A	N/A
Mean % TDG 2003-2023	**102.9**	**105.5**	**109.4**	**112.6**	**114.1**	**115.2**	**115.8**	**118.9**	**120.6**	**119.9**

Notes: N/A = data not available at that flow range

Radial Gate Study and Results

NorthWestern initiated a study of various configurations of spill over the Main Channel Dam in 2019 using different combinations of two of the four radial gates to measure changes in downstream TDG. Continued investigations were formalized in a FERC-approved TDG study during relicensing of the Project in the 2021 and 2022 spill seasons (NorthWestern 2022, 2023). Two gates were tested at a time to represent potential future operating conditions. Under normal spill operation, two radial gates remain closed and held "in reserve" for the purposes of flow restoration below the dam in the event of a plant trip at the powerhouses, or if needed for reservoir elevation control. The other two remaining radial gates are used for spill operations. During the study, each radial gate spill configuration was held for approximately 4 hours to allow the downstream TDG levels to stabilize. TDG was measured below the Main Channel Dam at the High Bridge monitoring site to track changes in TDG concentrations as radial gate configurations were tested. **Table 2-5** shows a summary of the results of this testing as well as data from previous testing on the radial gates, which was conducted in 2019 and 2020. The full results of this testing can be found in **Table A-1** in **Appendix A.**

Table 2-5. Maximum and minimum TDG by total Project flow at the High Bridge (HB) monitoring site, 2019-2022

Total Project 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
55,000-60,000[1]	121.6	3 and 4 open	119.6	1 and 2 open
55,000-60,000[2]	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

Overall, the study found that while the radial gate operational scenario that entrained the least amount of TDG differed at various river flows, utilizing non-adjacent radial gates generally entrains less TDG downstream than utilizing adjacent radial gates (i.e. Radial Gates 1 and 2 used together or Radial Gates 3 and 4 used together). Opening non-adjacent radial gates during spill operations will most likely minimize the amount of TDG entrained downstream, however 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 upstream face of the Main Channel and Dry Channel 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 metal stanchions on the dams 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 of water over 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 2018). 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, therefore radial gate operations should be conducted in a way to facilitate passage of debris and minimize the need for emergency stanchion removal.

Section 3.0 – Proposed Project Operations and TDG Monitoring Schedule

Section 3.1 – Spill Operations Sequence

Using the TDG data collected from 2019-2023, NorthWestern has developed a spill operations sequence to be implemented upon FERC approval of the new license. The updated spill operations sequence mimics the operations and intent of the 2010 TDG Control Plan, but incorporates the infrastructure of the four radial gates and their contribution to downstream TDG (**Appendix B**).

At lower total Project flows, when the fish passage facility is operating, the spill operations sequence will be designed to optimize upstream fish passage efficiency. This may include removing one panel or a combination of panels to attract fish to the fish ladder. Similar to the 2010 TDG Control Plan, spill panels will then be removed from the side of the dam opposite of the fish ladder to maintain reduced river velocities near the fish ladder. Only one radial gate, Radial Gate #1 (**Figure 2-3**), is planned to be used in the open position at this point in the sequence so that lower river velocities through the natural falls area can be maintained. Because the trash boom is connected to Radial Gate #1, that gate will be the primary means of passing debris downstream to prevent it from building up on the upstream face of the Main Channel Dam. Bays 13 through 15 on the Main Channel Dam, which abut Radial Gate #1, should remain closed throughout most of the spill sequence to avoid pulling debris under the trash boom resulting in debris buildup on those stanchions. Because utilizing non-adjacent radial gates together produces less downstream TDG than adjacent radial gates (**Table 2-5**), Radial Gate #3 will be used periodically for reservoir elevation control as dam panels are being removed, so that the water surface elevation of the reservoir can be maintained.

The maximum operational capacity at the fish ladder is 48,500 cfs, so when total Project flow exceeds this value, spill operations will then be designed to minimize TDG concentrations downstream. To minimize TDG concentrations downstream, the removal of the remaining spill panels on the Main Channel Dam will be done prior to utilizing Radial Gate #3 fully, which would occur at approximately 72,391 cfs. The radial gate study showed that operating Radial Gates #1 and #3 together at total Project flows above 65,000 cfs entrained the least amount of TDG downstream.

The complete sequence of spill operations is as follows with the approximate total river flow for each sequence shown in parentheses:

1. Removal of one or more panels from Bays 1 through 10 on the Main Channel Dam to be used as fish attractant flow (< 23,555 cfs).
2. Remove panels from Bays 34 through 26, sequentially, starting at Bay 34 on the Main Channel Dam (23,555–36,245 cfs).
3. Open Radial Gate #1 (36,246–47,245 cfs).
4. Remove panels from Bays 12, 23, 11, 22, 10, 21, 9, 20, 8, 19, 7, and 18, sequentially starting at Bay 12, to spread out the flow across the face of the Main Channel Dam (47,246–64,165 cfs).
5. Remove panels from Bays 6 through 1, sequentially starting at Bay 6, on the Main Channel Dam (64,166–72,390 cfs).
6. Open Radial Gate #3 on the Main Channel Dam (72,391–83,390 cfs).
7. Remove panels from Bays 12 through 1, sequentially starting at Bay 12, on the Dry Channel Dam (83,391–100,310 cfs).
8. Remove panels from Bays 13 through 15, sequentially starting at Bay 13, on the Main Channel Dam (100,311–104,540 cfs).
9. Open Radial Gate #2 on the Main Channel Dam (104,541–115,540 cfs).
10. Open Radial Gate #4 on the Main Channel Dam (115,541–126,540 cfs).

Section 3.2 – TDG Monitoring Schedule

TDG monitoring under this updated TDG Control Plan will occur annually for the first three years to validate the effectiveness of the plan. After the three-year validation period, the normal TDG monitoring schedule will continue in high water years where the most probable (50 percent) April 1 Natural Resources Conservation Service (NRCS) runoff forecast for the U.S. Geological Survey (USGS) Clark Fork River near Plains, Montana stream gage (12389000) is at or above 125 percent. This trigger value is an accurate predictor of years in which elevated concentrations of TDG are likely to be found. Monitoring will occur throughout the spring runoff season (April-July) at the same three established monitoring sites identified in **Section 2.3.1**.

In years where TDG is monitored at the Project, NorthWestern will submit collected TDG data to the DEQ and report the results of that monitoring effort to the Thompson Falls Fisheries TAC at the annual TAC meeting.

Section 4.0 – Discussion

The previously developed 2010 Total Dissolved Gas Control Plan for the Thompson Falls Project was designed to manage Project operations to minimize the entrainment of downstream TDG. Since late 2018, upgrades to infrastructure at the Main Channel Dam have changed how river flow is passed over the dam during the spill season. This updated plan addresses the changes to the project infrastructure, the new radial gates' effect on downstream TDG, and provides a sequence of operations for managing water during the spill season to both optimize upstream fish passage efficiencies and minimize downstream TDG concentrations.

Radial Gate #1 will be the first radial gate used during spill operations due to its location on the Main Channel Dam in relation to the trash boom. As debris builds up on the Main Channel Dam, Radial Gate #1 is used to flush that debris downstream to help maintain the structural integrity of the dam. The 2019-2022 radial gate testing concluded that operating non-adjacent radial gates in conjunction with one another generally entrained less downstream TDG than operating adjacent radial gates in that fashion. Because of this, Radial Gate #3 will be the next radial gate to be used for spill operations (**Table B-1** in **Appendix B**). Radial Gate #3 may also be periodically used for reservoir elevation control as dam panels are being either removed or installed throughout the spill operations sequence.

At total Project flows of 48,500 cfs or less, spill over the Main Channel Dam will be managed to optimize upstream fish passage efficiency. When total Project flow exceeds 48,500 cfs, the operational capacity of the fish ladder, spill will be managed to minimize the downstream concentrations of TDG. Coincidentally, this level of Project flow is where TDG concentrations have historically started to exceed 110 percent TDG at the Birdland Bay Bridge site and 120 percent TDG at the High Bridge site below the Main Channel Dam, necessitating the need for minimizing downstream TDG at this point in the spill operations sequence. **Section 3.1** and **Table B-1** in **Appendix B** outline the spill operations sequence to be used to accomplish this management strategy.

Since routing Project flows through the powerhouses results in lower downstream TDG than routing Project flows through the spillways, NorthWestern will prioritize using the powerhouses to pass Project flows over using the spillways in most circumstances. There are circumstances where this is not possible or feasible from an operations standpoint due to outages, negative market pricing, and grid reliability, which may necessitate the need to use the spillways instead of the powerhouses to pass Project flow. To minimize the impacts resulting from this, planned maintenance activities requiring the re-routing of flow from the powerhouses to the spillways will be scheduled outside of the spill season, whenever possible, to minimize Project TDG contributions downstream. There may be some unavoidable instances however where maintenance or construction timelines require units in the powerhouses to be offline during the spill season.

If future significant changes to Project infrastructure or management alter the way that water is routed through the Project, resulting in changes to the contribution of downstream TDG, NorthWestern will consult with DEQ to update the TDG Control Plan, if necessary, and submit the updated plan to FERC.

Section 5.0 – References

Montana Department of Environmental Quality (DEQ). 2019. Circular DEQ-7 Montana Numeric Water Quality Standards. June 2019. https://deq.mt.gov/files/Water/WQPB/Standards/PDF/DEQ7/DEQ-7.pdf. Accessed 3/24.

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NorthWestern Energy. 2022. Thompson Falls Hydroelectric Project, FERC Project No. 1869, Initial Study Report – Total Dissolved Gas Study. NorthWestern Energy, Butte, MT.

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Weitkamp, D. E, and M. Katz. 1980. A Review of Dissolved Gas Supersaturation Literature, Transactions of the American Fisheries Society, 109:6, 659-702.

Appendix A – Thompson Falls Radial Gate Testing Results

Table A-1. Results of radial gate testing at the Main Channel Dam and associated TDG monitoring at the High Bridge site conducted at the Project 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

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)
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

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	121.5
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

Appendix B – Thompson Falls Spill Operations Sequence

Table B-1. Spill operations sequence when total Project flow exceeds powerhouse capacity

Thompson Falls Spill Operations Sequence																																						
Main Channel Dam Bay/Gate Number and Number of Panels to be Removed																																						
Sequence Step	Bay Numbers															Gate Numbers		Bay Numbers						Gate Numbers		Bay Numbers									Total Panels	Number of Spill Gates Open	Total Flow	Upstream Fish Passage
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Gate 1	Gate 2	18	19	20	21	22	23	Gate 3	Gate 4	26	27	28	29	30	31	32	33	34				
1	1	*	*	*	*	*	*	*	*	*						Closed	Closed							Closed	Closed										1	0	23,555	Yes
2	1	*	*	*	*	*	*	*	*	*						Closed	Closed							Closed	Closed									6	7	0	24,965	Yes
3	1	*	*	*	*	*	*	*	*	*						Closed	Closed							Closed	Closed								6	6	13	0	26,375	Yes
4	1	*	*	*	*	*	*	*	*	*						Closed	Closed							Closed	Closed							6	6	6	19	0	27,785	Yes
5	1	*	*	*	*	*	*	*	*	*						Closed	Closed							Closed	Closed						6	6	6	6	25	0	29,195	Yes
6	1	*	*	*	*	*	*	*	*	*						Closed	Closed							Closed	Closed					6	6	6	6	6	31	0	30,605	Yes
7	1	*	*	*	*	*	*	*	*	*						Closed	Closed							Closed	Closed				6	6	6	6	6	6	37	0	32,015	Yes
8	1	*	*	*	*	*	*	*	*	*						Closed	Closed							Closed	Closed			6	6	6	6	6	6	6	43	0	33,425	Yes
9	1	*	*	*	*	*	*	*	*	*						Closed	Closed							Closed	Closed		6	6	6	6	6	6	6	6	49	0	34,835	Yes
10	1	*	*	*	*	*	*	*	*	*						Closed	Closed							Closed	Closed	6	6	6	6	6	6	6	6	6	55	0	36,245	Yes
11	1	*	*	*	*	*	*	*	*	*						Open	Closed							Closed	Closed	6	6	6	6	6	6	6	6	6	55	1	47,245	Yes
12	1	*	*	*	*	*	*	*	*	*		6				Open	Closed							Closed	Closed	6	6	6	6	6	6	6	6	6	61	1	48,655	No
13	1	*	*	*	*	*	*	*	*	*		6				Open	Closed						6	Closed	Closed	6	6	6	6	6	6	6	6	6	67	1	50,065	No
14	1	*	*	*	*	*	*	*	*	*	6	6				Open	Closed						6	Closed	Closed	6	6	6	6	6	6	6	6	6	73	1	51,475	No
15	1	*	*	*	*	*	*	*	*	*	6	6				Open	Closed					6	6	Closed	Closed	6	6	6	6	6	6	6	6	6	79	1	52,885	No
16	1	*	*	*	*	*	*	*	*	6	6	6				Open	Closed					6	6	Closed	Closed	6	6	6	6	6	6	6	6	6	85	1	54,295	No
17	1	*	*	*	*	*	*	*	*	6	6	6				Open	Closed				6	6	6	Closed	Closed	6	6	6	6	6	6	6	6	6	91	1	55,705	No
18	1	*	*	*	*	*	*	*	6	6	6	6				Open	Closed				6	6	6	Closed	Closed	6	6	6	6	6	6	6	6	6	97	1	57,115	No
19	1	*	*	*	*	*	*	*	6	6	6	6				Open	Closed			6	6	6	6	Closed	Closed	6	6	6	6	6	6	6	6	6	103	1	58,525	No
20	1	*	*	*	*	*	*	6	6	6	6	6				Open	Closed			6	6	6	6	Closed	Closed	6	6	6	6	6	6	6	6	6	109	1	59,935	No
21	1	*	*	*	*	*	*	6	6	6	6	6				Open	Closed		6	6	6	6	6	Closed	Closed	6	6	6	6	6	6	6	6	6	115	1	61,345	No
22	1	*	*	*	*	*	6	6	6	6	6	6				Open	Closed		6	6	6	6	6	Closed	Closed	6	6	6	6	6	6	6	6	6	121	1	62,755	No
23	1	*	*	*	*	*	6	6	6	6	6	6				Open	Closed	6	6	6	6	6	6	Closed	Closed	6	6	6	6	6	6	6	6	6	127	1	64,165	No
24	1	*	*	*	*	6	6	6	6	6	6	6				Open	Closed	6	6	6	6	6	6	Closed	Closed	6	6	6	6	6	6	6	6	6	133	1	65,575	No
25	1	*	*	*	6	6	6	6	6	6	6	6				Open	Closed	6	6	6	6	6	6	Closed	Closed	6	6	6	6	6	6	6	6	6	139	1	66,985	No
26	1	*	*	6	6	6	6	6	6	6	6	6				Open	Closed	6	6	6	6	6	6	Closed	Closed	6	6	6	6	6	6	6	6	6	145	1	68,395	No
27	1	*	6	6	6	6	6	6	6	6	6	6				Open	Closed	6	6	6	6	6	6	Closed	Closed	6	6	6	6	6	6	6	6	6	151	1	69,805	No
28	1	6	6	6	6	6	6	6	6	6	6	6				Open	Closed	6	6	6	6	6	6	Closed	Closed	6	6	6	6	6	6	6	6	6	157	1	71,215	No
29	6	6	6	6	6	6	6	6	6	6	6	6				Open	Closed	6	6	6	6	6	6	Closed	Closed	6	6	6	6	6	6	6	6	6	162	1	72,390	No
30	6	6	6	6	6	6	6	6	6	6	6	6				Open	Closed	6	6	6	6	6	6	Open	Closed	6	6	6	6	6	6	6	6	6	162	2	83,390	No

*At total Project flows below 48,500 cfs, one panel or a combination of panels may be removed from the Main Channel Dam, Bays 1-10, and used for attraction flow to the upstream fish passage facility. This panel may be moved periodically as needed to optimize fish passage efficiency.

NorthWestern Energy

Thompson Falls Spill Operations Sequence

Dry Channel Dam Bay Number and Number of Panels to be Removed

Sequence Step	Bay Numbers												Main Dam Flow	Total Panels	Number of Spill Gates Open	Total Flow	Upstream Fish Passage
	1	2	3	4	5	6	7	8	9	10	11	12					
31												6	83,390	168	2	84,800	No
32											6	6	83,390	174	2	86,210	No
33										6	6	6	83,390	180	2	87,620	No
34									6	6	6	6	83,390	186	2	89,030	No
35								6	6	6	6	6	83,390	192	2	90,440	No
36							6	6	6	6	6	6	83,390	198	2	91,850	No
37						6	6	6	6	6	6	6	83,390	204	2	93,260	No
38					6	6	6	6	6	6	6	6	83,390	210	2	94,670	No
39				6	6	6	6	6	6	6	6	6	83,390	216	2	96,080	No
40			6	6	6	6	6	6	6	6	6	6	83,390	222	2	97,490	No
41		6	6	6	6	6	6	6	6	6	6	6	83,390	228	2	98,900	No
42	6	6	6	6	6	6	6	6	6	6	6	6	83,390	234	2	100,310	No

Thompson Falls Spill Operations Sequence

Main Channel Dam Bay/Gate Number and Number of Panels to be Removed

Sequence Step	Bay Numbers															Gate Numbers		Bay Numbers						Gate Numbers		Bay Numbers									Total Panels	Number of Spill Gates Open	Total Flow	Upstream Fish Passage
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Gate 1	Gate 2	18	19	20	21	22	23	Gate 3	Gate 4	26	27	28	29	30	31	32	33	34				
43	6	6	6	6	6	6	6	6	6	6	6	6	6			Open	Closed	6	6	6	6	6	6	Open	Closed	6	6	6	6	6	6	6	6	6	240	2	101,720	No
44	6	6	6	6	6	6	6	6	6	6	6	6	6	6		Open	Closed	6	6	6	6	6	6	Open	Closed	6	6	6	6	6	6	6	6	6	246	2	103,130	No
45	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	Open	Closed	6	6	6	6	6	6	Open	Closed	6	6	6	6	6	6	6	6	6	252	2	104,540	No
46	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	Open	Open	6	6	6	6	6	6	Open	Closed	6	6	6	6	6	6	6	6	6	252	3	115,540	No
47	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	Open	Open	6	6	6	6	6	6	Open	Open	6	6	6	6	6	6	6	6	6	252	4	126,540	No

Appendix C - Documentation of Consultation

From: Tollefson, Jordan
To: Metzner, Gabrielle; Bushnell, Ella; Kron, Darrin; Keenan Storrar; "Erik.Englebert@mt.gov"
Cc: "Welch, Andrew"; "Babcock, Sarah (Sady)"; ggillin@geiconsultants.com
Subject: Thompson Falls Total Dissolved Gas Control Plan - Final Version
Date: Monday, May 20, 2024 5:32:00 PM
Attachments: 2024 Thompson Falls TDG Control Plan 5.20.24 Final Version.pdf

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Thank you all for taking the time to review and provide comments on the Thompson Falls TDG Control Plan. NorthWestern has incorporated your suggestions by providing the following updates to the document:

- Language has been added to Section 3.1 and Section 4.0 to further clarify how Radial Gates #1 and #3 will be used to minimize the downstream concentrations of TDG to the best extent practicable.
- Language has been added to Section 3.2 discussing TDG data submittal to DEQ in years when TDG data are collected.
- Language has been added to Section 4.0 to address powerhouse utilization to reduce downstream TDG and the scheduling of future planned maintenance and construction activities outside of the spring runoff period whenever possible.

Attached is the final version of the TDG Control Plan for your records. We will be submitting the plan to FERC this week to satisfy the Additional Information Request for our License application.

Jordan Tollefson
Hydro Compliance Professional
Jordan.Tollefson@NorthWestern.com
O (406) 443-8907
C (406) 565-3879
208 N Montana Avenue, Suite 200
Helena, MT 59601

From:	Storrar, Keenan
To:	Tollefson, Jordan; Metzner, Gabrielle; Bushnell, Ella; Kron, Darrin
Cc:	Welch, Andrew; ggillin@geiconsultants.com; Babcock, Sarah (Sady); Englebert, Erik
Subject:	[EXTERNAL] RE: Thompson Falls TDG Control Plan Draft for Agency Review
Date:	Monday, May 6, 2024 9:31:20 AM
Attachments:	image002.png image003.png image004.png image005.png image006.png image007.png

Jordan,

DEQ has reviewed the Thompson Falls TDG Control Plan proposal and is providing these comments:

1. Data submission: The plan includes a trigger for when TDG data will be collected. Please submit instantaneous TDG data via EQuIS EDD format to MT DEQ. An alternative format is acceptable if the data is continuously collected by an insitu sonde.
2. Utilize Powerhouses to the Maximum Extent Practicable In Lieu of Spilling: "TDG measurements collected above the Project and below the powerhouses in 2003 found that TDG in the powerhouse tailrace was generally 1 to 2 percent lower than TDG upstream of the powerhouse" (TDG Control Plan). The Powerhouse can pass a maximum of ~23,300 cfs. The plan should include a narrative that the powerhouse capacity will be fully utilized to the maximum extent practicable to prevent spilling and the powerhouse turbines should be scheduled to be taken off line for maintenance or repair outside of the spring runoff/peak flow season to minimize TDG concentrations in the Clark Fork River downstream of the Project.
3. Incorporate Radial Gate Study Results into Spill Operations Sequence: "NorthWestern initiated a study of various configurations of spill over the Main Channel Dam in 2019-2022 using different combinations of two of the four radial gates to measure changes in downstream TDG. Two gates were tested at a time to represent potential future operating conditions" (TDG Control Plan). The 'Appendix A – Thompson Falls Radial Gate Testing Results' shows the most advantageous radial gate opening sequences minimizing TDG levels at the High Bridge Site for flows ranging from 30,000 cfs up to 85,000 cfs. It does not appear the Thompson Falls Spill Operations Sequence in Appendix B utilizes these data in the best practicable manner to minimize TDG concentrations in the Clark Fork River downstream of the Project. The Spill Operations Sequence proposes to open Gate 1 when spill reaches 47,245 cfs and proposes to open Gate 2 when spill reaches 83,390 cfs. The Spill Operations Sequence in Appendix B should consider incorporating the Radial Gate Study spill sequencing

results to minimize TDG concentrations in the Clark Fork River downstream of the Project.

Let me know if you have any questions.

Thank you,

Keenan Storrar | 401/318 coordinator
Water Protection Bureau
Montana Department of Environmental Quality
Office: 406-444-2734

Montana Department of Environmental Quality

How did we do? »

From: Tollefson, Jordan <Jordan.Tollefson@northwestern.com>
Sent: Friday, April 5, 2024 4:02 PM
To: Storrar, Keenan <Keenan.Storrar@mt.gov>; Metzner, Gabrielle <Gabrielle.Metzner@mt.gov>; Bushnell, Ella <Ella.Bushnell@mt.gov>; Kron, Darrin <dkron@mt.gov>
Cc: Andy Welch <andrew.welch@northwestern.com>; ggillin@geiconsultants.com; Babcock, Sarah (Sady) <Sady.Babcock@northwestern.com>
Subject: [EXTERNAL] Thompson Falls TDG Control Plan Draft for Agency Review

Hello,

NorthWestern has developed an updated Total Dissolved Gas (TDG) Control Plan for the Thompson Falls Project, and is submitting this draft to DEQ for a 30-day agency review prior to our submittal to FERC. Please see the attached draft of the plan and provide any comments that you may have on the plan by Tuesday, May 7th. If you have any questions, please don't hesitate to reach out to me about this. I hope you all have a wonderful weekend!

Jordan

Jordan Tollefson
Hydro Compliance Professional
Jordan.Tollefson@NorthWestern.com
O (406) 443-8907
C (406) 565-3879
208 N Montana Avenue, Suite 200
Helena, MT 59601