

# 2021 TOTAL DISSOLVED GAS REPORT



**U.S. Army Corps  
of Engineers  
Northwestern Division**

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**Spill at Bonneville Dam**

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Columbia Basin Water Management Division  
Reservoir Control Center  
Water Quality Unit

January 2022

# 2021 TOTAL DISSOLVED GAS REPORT

## COLUMBIA RIVER BASIN

*January 2022*

*Water Quality Unit  
Reservoir Control Center, Columbia Basin Water Management Division  
U. S. Army Corps of Engineers, Northwestern Division  
Portland, Oregon*

*Including Material Provided by:  
Portland District – U.S. Geological Survey (Portland Office)  
Walla Walla District – U.S. Geological Survey (Kennewick Office)  
Seattle District – Columbia Basin Environmental  
Fish Passage Center*

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The appendices to this report are available on the internet:

[http://pweb.crohms.org/tmt/wqnew/tdg\\_and\\_temp/2021/](http://pweb.crohms.org/tmt/wqnew/tdg_and_temp/2021/)

## List of Acronyms

The following acronyms are used throughout this report.

BiOp	Biological Opinion
BPA	Bonneville Power Administration
Corps	U.S. Army Corps of Engineers
CRS	Columbia River System
CRSO EIS	Columbia River System Operations Environmental Impact Statement
ESA	Endangered Species Act
FCOP	Flood Control Operating Plan
FMS	fixed monitoring station
FOP	Fish Operations Plan
GBT	gas bubble trauma
HEC-ResSim	Hydrologic Engineering Center's Reservoir System Simulation model
kcfs	thousand cubic feet per second
kaf	thousand acre-feet
Maf	million acre-feet
NMFS	National Oceanic and Atmospheric Administration, National Marine Fisheries Service
NWRFC	Northwest River Forecast Center
ODEQ	Oregon Department of Environmental Quality
PUD	Public Utility District
QA/QC	quality assurance/quality control
RCC	Reservoir Control Center
Reclamation	United States Bureau of Reclamation
SYSTDG	System total dissolved gas model used to estimate TDG production
TDG	total dissolved gas
TMT	Technical Management Team
TMDLs	Total Maximum Daily Loads
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
WDOE	Washington Department of Ecology
WQS	Water Quality Standards
WY	water year

## Terminology

The U.S. Army Corps of Engineers (Corps) provides the following definitions used throughout this report.

**7Q10 Flows:** The average peak annual flows for seven consecutive days that has a recurrence interval of 10 years, and at these flows, the ODEQ and WDOE TDG criteria do not apply.

**Action Agencies:** The three Federal agencies responsible for the operation of the Columbia River System or FCRPS projects are the Corps, Bureau of Reclamation (Reclamation), and Bonneville Power Administration (BPA).

**CRS:** The Columbia River System refers to the fourteen federal dam and reservoir projects within the Federal Columbia River Power System that are operated as a coordinated water management system for multiple congressionally authorized project purposes.

**Data Quality Events:** Data quality events occur when the Corps cannot evaluate TDG levels because the FMS gauge malfunctioned resulting in missing or erroneous data.

**Fish Passage Spill (Planned Spill):** The Corps provides spill for the benefit of juvenile fish passage at the four lower Snake River and four lower Columbia River dams in accordance with the operative biological opinions and in a manner that is consistent with the Clean Water Act and within the state TDG standards. The Corps also provides spill for the benefit of adult fish passage at the four lower Columbia River dams. Spill operations for juvenile fish passage are consistent with the provisions outlined in the 2020 NOAA Fisheries Columbia River System Biological Opinion (2020 BiOp), the Corps' requirements under the Endangered Species Act, and is the subject of ongoing consultation and communications with the relevant wildlife agencies to ensure consistency with the Act.

**Gas Cap:** The applicable State TDG WQS (in percent TDG). The TDG standard for the states of Washington and Oregon is 110%. Both states have provided exceptions to the TDG standard for juvenile fish passage spill operations on the lower Snake and lower Columbia rivers.

**Hydraulic capacity:** The maximum water flow rate that a hydropower facility can pass through the turbines. Capacity can be limited by outages, operating limits, and the carrying of mandatory power reserves by the project.

**Forced Spill:** Forced spill is driven largely by hydrologic capacity at each dam. It is the quantity of water that exceeds the capacity of a dam to either temporarily store the water upstream of the dam or pass the water through its turbines. In these circumstances, water must be released through the spillway. Forced spill occurs due to either **Lack of Load** or **Lack of Turbine**, but can also occur as a result of the management of reservoirs for flood

risk<sup>1</sup>, scheduled or unscheduled turbine unit outages or transmission outages of various durations, passing debris, or any other operational and/or maintenance activities required to manage dam facilities for safety and authorized project uses.

1. **Lack of Load Spill:** Occurs when the available market for hydropower is less than the power that could be produced by the current river flow with available turbine capacity. When BPA cannot access sufficient markets to sell hydropower and there is insufficient storage capability, the river flow must be released over the spillway or through other regulating outlets. Lack of load spill generally occurs during times of high flows (e.g., in the spring when power demands are low both in California and the Pacific Northwest). Releases from upstream storage dams during high load periods (generally morning and evening) can result in high flows at downstream dams during low load periods (e.g., middle of the night), causing lack of load spill. Lack of load spill is managed on a system-wide basis to distribute TDG levels across the Federal projects using the spill priority list.
2. **Lack of Turbine Spill:** Occurs when flows exceed the hydraulic capacity of the available power generation facilities at a specific dam. Lack of turbine spill can be affected by high river flows, planned and unplanned unit outages, planned and unplanned transmission outages, and other transmission constraints. Any of these conditions physically limit the potential for hydropower production. Lack of turbine spill will generally be the amount of project outflow in excess of the maximum amount that can be released through all available generators and other outlet structures (e.g., sluiceways and fish ladders). In general, when this condition occurs, the affected project will be operating at maximum generation, but within the Fish Passage Plan turbine operating criteria capability to minimize the amount of spill.

Lack of turbine spill can also occur when turbines cannot be used because their capacity must be held in reserve to provide mandatory reserve power capacity (reserves) for contingencies and load balancing. **Reserves** (Reserve Power Capacity) are the amount of generation capacity above the amount currently in use that is immediately available to maintain system reliability. At projects that must carry reserve power capacity, these projects can only be loaded to the maximum available generation minus the reserve capacity allocated to that project. Spill for maintaining reserves primarily occurs at Grand Coulee, Chief Joseph, The Dalles, John Day, Bonneville, and occasionally McNary dams.

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<sup>1</sup> The Corps directs operations of storage projects in the Columbia River Basin to manage flood risk. Storage reservoir pools are drafted in the winter and early spring to provide space to capture part of the spring runoff, reducing peak flows in the river. This flood risk management operation may require spill from storage reservoirs, which may result in elevated levels of TDG in the river system. The Corps and other action agencies work to manage system flood risk operations in a manner that reduces the need to spill at levels that exceed TDG water quality standards; however, there are conditions in which fulfilling the Corps' flood risk management authorities necessitates drafting storage reservoirs.

(c) **Special Spill Events:** Occur for the purposes of passing debris or operational and/or maintenance activities required to manage dam facilities for safety and multiple uses. These are infrequent and generally of short duration.

**2020 BiOps:** The governing NMFS and USFWS Biological Opinions for the Columbia River System.

**Percent TDG:** Percent of total dissolved gas saturation (TDG) or concentration in the water-body. This may also appear as %TDG in the text or tables.

**Performance Standard Spill** – Performance standard spill is a NOAA Fisheries term and refers to spill levels intended to meet NOAA’s performance standard testing, as described in the 2008 FCRPS Biological Opinion and accompanying administrative record.

**Regulatory Methods** - The regulatory method refers the TDG calculation methodology determined by the gas cap that applies on a specific date, at a specific location. When and where multiple calculation methods apply, ‘regulatory’ represents the calculation that results in the greater value.

**Spill Cap** – The spill level (flow through the spillway measured in kcfs) at each project that is estimated to maximize spill to a level that meets, but does not exceed, the gas cap in the tailrace and the next downstream forebay (if applicable).

**Spill Priority List:** Identifies the order and amount of spill at the Corps’ Columbia River Basin dams and Grand Coulee Dam for management of lack of load spill and the expected TDG production system-wide. The Spill Priority List is used throughout the year during times of forced spill. The Spill Priority List consists of levels based on ascending TDG values, a spill rate for each project that is estimated to produce the TDG values and an order of projects.

**TDG Exceedance:** An exceedance occurs when TDG levels exceed applicable state water quality standards and applicable TDG modification (Oregon) and criteria adjustments (Washington).

**TMT:** The Technical Management Team (TMT) is an interagency sovereign technical group responsible for making recommendations on operations for fish to the Federal agencies with authority to operate FCRPS projects. This group is comprised of representatives from sovereign entities including five Federal agencies: BPA, Reclamation, National Oceanic and Atmospheric Administration (NOAA) Fisheries, U.S. Fish and Wildlife Service (USFWS), Corps, four states (Idaho, Oregon, Montana, and Washington), and participating Tribes.

**Unit Outage:** A unit outage is a period when a generating unit cannot be in operation because of maintenance or repairs.

# Program Description

## Overview

Total Dissolved Gas (TDG) is impacted by the U.S. Army Corps of Engineers' (Corps) projects in the mainstem Columbia and Snake rivers in the states of Oregon and Washington. Flow passing over the spillway of a dam can cause TDG concentrations that are greater than background levels. As TDG travels downstream it is influenced by environmental factors including water temperature and wind.

Juvenile fish passage spill occurs generally from April through August. The volumes and duration of fish passage spill at each project in 2021 were implemented consistent with spill operations for juvenile fish passage and the regional forum process for adaptive management and in-season management provisions outlined in the Record of Decision for the Columbia River System Operations Environmental Impact Statement (CRSO EIS), National Marine Fisheries Service and U.S. Fish and Wildlife Service Biological Opinions (2020 BiOps)<sup>2</sup>, the Extension and Amendment of the 2008 Columbia Basin Fish Accords (Accord Extensions), the Corps' requirements under the Endangered Species Act (ESA), and the ongoing consultation and communications with the relevant wildlife agencies to ensure consistency with the Act. The governing documents and project operations are summarized in the Water Management Plan (<https://pweb.crohms.org/tmt/documents/wmp/2021/>).

This report describes the Corps' Columbia River Basin spill and water quality monitoring program for 2021 and addresses the Corps' reporting responsibilities related to the 2020 Oregon Department of Environmental Quality (ODEQ) TDG modification, the 2020 Washington Department of Ecology (WDOE) TDG rule change, and the 2002 and 2003 TDG Total Maximum Daily Loads (TMDLs) for the lower Columbia and lower Snake rivers.

ODEQ requires an annual TDG report summarizing the spill season and detailing the following: (a) flow and runoff descriptions, (b) spill quantities and durations, (c) quantities of water spilled for fish versus spill for other reasons, (d) data results from the physical and biological monitoring programs, including incidences of gas bubble trauma regardless of sample size, (e) evaluation of the relationship between observation of non-salmonid gas bubble trauma monitoring and exposure to elevated TDG levels, (f) biological or physical studies of spillway structures and prototype fish passage devices to test spill at operational levels, and (g) implementation of gas abatement measures identified through adaptive management. This report also includes documentation on the performance of the TDG monitoring system that is required in the Terms and Conditions outlined in the 2020 BiOps.

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<sup>2</sup> The Corps, in coordination with the other Action Agencies, and NMFS, employs the Regional Implementation Oversight Group (RIOG) and technical teams including the Technical Management Team (TMT) and Fish Passage Operations & Maintenance (FPOM) coordination group, to coordinate with state, tribal and other federal experts for recommendations for implementing operations consistent with the 2020 BiOps.

## State Water Quality Standards (WQS) for TDG

The Corps manages spill for fish passage consistent with the State of Washington and the State of Oregon TDG WQS.<sup>3,4</sup> WDOE WQS allows spring juvenile fish passage spill operations to generate specified TDG levels in project tailraces (up to 125% TDG for 12 hours; 126% TDG for 2 hours), so long as the spring juvenile fish passage spill operations do not exceed the spill levels and durations reviewed in applicable ESA consultation documents. The EPA subsequently approved the rule change and found that the ESA consultation documents' language ensures that any spring spill regime using the revised criteria must be performed in accordance with the spill levels and durations evaluated in ESA consultation documents for effects to ESA-listed species of all life stages, including juvenile out-migrating salmonids, resident salmonids, and adult migrating salmonids. EPA's approval of the rule further states that "compliance with the ESA consultation documents is a condition precedent for the revised criteria and so the criteria are not applicable for the purposes of the CWA (i.e. have no effect for CWA purposes) without the ESA consultation documents addressing spill operations that result in TDG saturation levels above the pre-existing criterion." *Letter to WDOE from EPA Re: The EPA's Action on Revisions to the [WDOE]'s Surface Water Quality Standards for the Site-Specific Total Dissolved Gas Criteria in the Columbia and Snake Rivers, and Other Water Quality Standards Revisions dated March 5, 2020, page 9.*

The ODEQ approved a change to its TDG WQS (up to 125% TDG for 12 hours, 127% TDG for 2 hours), so long as spring spill is "applied in a manner consistent with the applicable requirements of the federal [ESA]." *Order Approving a Modification to the Oregon's Water Quality Standard for Total Dissolved Gas in the Columbia River Mainstem dated February 11, 2020, page 4.* Both states have thus accommodated levels of TDG above 110% for fish passage spill operations for ESA-listed juvenile salmonids at Corps projects on the lower Snake and lower Columbia rivers, as follows:

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<sup>3</sup> WASH. ADMIN. CODE § 173-201A-200(I)(f) provides the maximum TDG criteria for each of the aquatic life use categories and displays Table 200 (I)(f) that states: "Total dissolved gas shall not exceed 110 percent of saturation at any point of sample collection." The code also addresses exceptions and adjustments, including a provision allowing for an adjustment of the TDG criteria to aid fish passage over hydroelectric dams.

<sup>4</sup> OR. ADMIN. R. 340-041-0031 provides in part: "the concentration of TDG relative to atmospheric pressure at the point of sample collection may not exceed 110 percent of saturation." OR. ADMIN. R. 340-041-104(3) identifies findings the Environmental Quality Commission must make for the purpose of allowing increased spill for salmon migration. See <https://www.oregon.gov/deq/wq/Documents/columbiaUSACEtmdlorder.pdf>

## Washington Administrative Code

### WAC 173-201A-200(1)(f)(ii) and WAC 173-201A-200(1)(f)(ii)(A)

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(ii) The TDG criteria may be adjusted to aid fish passage over hydroelectric dams that spill for anadromous juvenile fish as of the 2020 spill season. The elevated TDG levels are intended to allow increased fish passage without causing more harm to fish populations than caused by turbine fish passage. The following special fish passage exemptions for the Snake and Columbia Rivers apply when spilling water at dams is necessary to aid fish passage:

(A) TDG must not exceed:

- An average of one hundred fifteen percent as measured in the forebays of the next downstream dams and must not exceed an average of one hundred twenty percent as measured in the tailraces of each dam (these averages are calculated as an average of the twelve highest hourly readings in a calendar day, relative to atmospheric pressure); and
- A maximum TDG saturation level of one hundred twenty-five percent calculated as an average of the two highest hourly TDG measures in a calendar day during spillage for fish passage.

### WAC 173-201A-200(1)(f)(ii)(B)

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(B) To further aid fish passage during the spring spill season (generally from April through June), spill may be increased up to the following levels as measured at the tailrace fixed site monitoring location:

- A maximum TDG saturation level of one hundred twenty-five percent calculated as an average of the twelve highest hourly TDG measures in a calendar day; and
- A maximum TDG saturation level of one hundred twenty-six percent calculated as an average of any two consecutive hourly TDG measures. These TDG criteria may be applied in place of (f)(ii)(A) of this subsection during spring spill operations when applied in accordance with the following conditions:

(I) In addition to complying with the requirements of this chapter, the tailrace maximum TDG criteria at hydropower dams shall be applied in accordance with Endangered Species Act consultation documents associated with spill operations on the Snake and Columbia rivers, including operations for fish passage. The Endangered Species Act consultation documents are those by which dams may legally operate during the time that the adjusted criteria in (f)(ii)(B) of this subsection are in use.

(II) Application of the tailrace maximum TDG criteria must be accompanied by a department approved biological monitoring plan designed to measure impacts of fish exposed to increased TDG conditions throughout the spring spill season. Beginning in the year 2021, plans must include monitoring for non-salmonid fish species and must continue for a minimum of five years, and thereafter as determined by the department.

(III) TDG must be reduced to allowances specified in (f)(ii)(A) of this subsection if the calculated incidence of gas bubble trauma in salmonids (with a minimum sample size of fifty fish required weekly) or non-salmonids (with a minimum sample size of fifty fish required weekly) exceeds:

- Gas bubble trauma in non-paired fins of fifteen percent; or
- Gas bubble trauma in non-paired fins of five percent and gas bubbles occlude more than twenty-five percent of the surface area of the fin.

If gas bubble trauma exceeds these biological thresholds, additional monitoring must demonstrate the incidence of gas bubble trauma below biological thresholds before TDG can be adjusted to allowances specified in this subsection. Gas bubble trauma monitoring data shall be excluded from comparison to biological thresholds when higher than normal river flow contributes to excess spill above the ability to meet (f)(ii)(B) of this subsection. This monitoring data exclusion shall apply for one full calendar day after reduced river flow allows attainment of (f)(ii)(B) of this subsection.

### **Oregon Water Quality Standard Modification**

The Environmental Quality Commission approves the following modification to the statewide standard for total dissolved gas (OAR 340-41-0031(2)) of 110 percent for the lower Columbia River at McNary, John Day, The Dalles and Bonneville dams, as provided for in OAR 340-41-0104(3):

1. The total dissolved gas standard for the Columbia River as measured in the tailraces of McNary, John Day, The Dalles, and Bonneville dams is 125 percent for the period from April 1 through June 15.
2. The total dissolved gas standard for the Columbia River as measured in the tailraces of McNary, John Day, The Dalles, and Bonneville dams is 120 percent for the period from June 16 through Aug. 31.
3. These limits do not apply when the stream flow exceeds the seven-day, ten-year frequency flood.
4. The DEQ Director may approve additional periods of application of this modification, beyond the April 1 to Aug. 31 period, subject to subsections 7.a) to 7.d) for reasons including passing Spring Creek Hatchery fish releases, maintenance activities, and biological or physical studies of spillway structures and prototype fish passage devices. The Corps must notify DEQ in writing describing the proposed action, the purpose of the action and dates of action at least one week prior to the spill. The Corps must obtain written approval from the Director prior to such spill.
5. The modified total dissolved gas standards will apply for five years, 2020, 2021, 2022, 2023 and 2024.
6. Voluntary fish passage spill during the spring spill season, occurring from April 1 through June 15, is subject to the following conditions:
  - a. Spill at a dam must be reduced when:
    - i. Instantaneous total dissolved gas levels exceed 127 percent of saturation, calculated as the average of any two consecutive hourly TDG measurements in the tailrace of the dam; or

- ii. The average of the twelve highest hourly TDG measurements in the tailrace of the dam in a calendar day exceeds 125 percent.
  - b. Spill at a dam must be reduced to 120 percent as calculated in 7.a)i. when:
    - i. The calculated incidence of gas bubble trauma in salmonids (with a minimum sample size of fifty fish required weekly) or non-salmonids (with a minimum sample size of fifty fish required weekly) exceeds gas bubble trauma in non-paired fins of fifteen percent, or gas bubble trauma in non-paired fins of five percent and gas bubbles occlude more than twenty-five percent of the surface area of the fin. If gas bubble trauma exceeds these biological thresholds, additional monitoring must demonstrate the incidence of gas bubble trauma below biological thresholds before TDG can be increased to the level specified in this order. Gas bubble trauma monitoring data shall be excluded from comparison to biological thresholds when higher than normal river flow contributes to excess spill above 125 percent. This monitoring data exclusion shall apply for one full calendar day after reduced river flow allows attainment of 125 percent TDG levels in the tailrace of the dam.
  - c. The tailrace maximum TDG criteria for spring spill in this modification will be applied in a manner consistent with the applicable requirements of the federal Endangered Species Act.
  - d. Physical monitoring must occur and be adequate for implementing the requirements of this order.
  - e. Application of the tailrace maximum TDG criteria must be accompanied by a DEQ-approved biological monitoring plan designed to measure impacts to fish exposed to increased TDG conditions throughout the spring spill season. Beginning in the year 2021, plans must include monitoring for non-salmonid fish species. Gas bubble trauma monitoring for juvenile salmonids may be halted if there is a high mortality risk due to compounded effects of the evaluation procedure and adverse environmental factors such as high stream temperatures.
- 7. Voluntary fish passage spill during the summer spill season, occurring from June 16 through Aug. 31, is subject to the following conditions:
  - a) Spill at a dam must be reduced when:
    - i. The average of the twelve highest hourly TDG measurements in the tailrace of the dam in a calendar day exceeds 120 percent of saturation; or
    - ii. Instantaneous total dissolved gas levels exceed 125 percent of saturation in the tailrace of the dam, calculated as the average of the two highest hourly total dissolved gas measures in a calendar day.
  - b) The DEQ Director may halt the voluntary spill program or require reductions in voluntary spill to reduce TDG levels if voluntary spill results in biological threshold exceedances when:
    - i. More than 15 percent of salmonids examined show signs of gas bubble disease in their non-paired fins, or
    - ii. More than five percent of salmonids examined show signs of gas bubble trauma in their non-paired fins where more than 25 percent of the surface area of the fin is occluded by gas bubbles.

- c) Physical monitoring must occur and be adequate for implementing the requirements set out in this order.
- d) Application of the tailrace maximum TDG criteria must be accompanied by a DEQ-approved biological monitoring plan designed to measure impacts to fish exposed to increased TDG conditions throughout the summer spill season. Beginning in the year 2021, plans must include monitoring for non-salmonid fish species. Gas bubble trauma monitoring for juvenile salmonids may be halted if there is a high mortality risk due to compounded effects of the evaluation procedure and adverse environmental factors such as high stream temperatures.

## **Implementation of Gas Abatement Measures**

The Oregon TDG modification requests an update on the implementation of gas abatement measures through adaptive management. TDG management measures are currently in place for limiting Columbia and Snake River environments to acceptable TDG criteria levels for fish during most of the fish passage season. Significant TDG abatement has been accomplished through structural and operational improvements, but limited opportunities are available for further TDG reduction during flood flow conditions. The 2018 Update to the TDG Gas Abatement Plan and Appendix B of this document provide the status of the Corps' TDG TMDL implementation activities.

## **TDG Management Operations**

The TDG Management Plan is an appendix to the Water Management Plan (found here: <https://pweb.crohms.org/tmt/documents/wmp/> ) and describes forced and planned spill, use of the spill priority list, the process for setting spill caps, TDG management policies, and the TDG monitoring program. During spring and summer spill, WDOE's and ODEQ's WQSSs use the same method for calculating a daily value of TDG: the average of the 12 highest hourly readings in a calendar day (termed Ave12hrMax). Daily averages are shown in the web report:

[https://pweb.crohms.org/ftppub/water\\_quality/12hr/](https://pweb.crohms.org/ftppub/water_quality/12hr/).

In 2021, the 12-hour metric was more restrictive than the 2-hour metric.

The spill priority list is a lack of load TDG management tool that has been developed for forced spill that results in exceeding the state TDG standards when lack of load conditions require spill. The Corps works with the region to develop the spill priority list identifying the order in which the projects spill in order to minimize TDG systemwide. This list calls for adding spill incrementally across all federally owned projects to prevent excessively high TDG levels from being generated in concentrated river reaches. Excess spill is spread over Federal projects to hold peak TDG levels to targeted TDG thresholds in 2 to 5 percent increments.

## **Operating Conditions**

### **Weather**

The 2021 Water Year (WY) was notable due to high temperatures and low precipitation (Table 1). A fairly wet fall and winter in northern portions of the basin allowed snowpack to build in the northern portion of the basin, however, by April, a blocking upper level ridge developed just off the West Coast which prevented wetting storms from crossing all but the farther north areas of the Columbia Basin. Basin average precipitation in the March-April period was only 32 percent of normal – the driest March-April period since reliable basin-average records became available in 1977.

By May, the entire Columbia Basin, particularly the southern half, was in a drought, however, as temperatures warmed above average across the south, they remained slightly below average across the north where considerable snowpack from earlier in the winter remained.

A heat wave on 26-30 June became the most notable weather event of the year as over two dozen all-time record highs were set in British Columbia, Oregon, and Washington, including: Portland, OR at 46.7°C/116°F; Spokane, WA at 42.8°C/109°F, Seattle, WA at 42.2°C/108°F, Kamloops, BC (45.8°C/114°F), and Victoria, BC (39.8°C/104°F).

While the June heat wave was, by far, the hottest period of the summer, two additional heat waves impacted the region on 29-31 July and 11-14 August, with the August heat wave the more intense of the two accompanied by several days of high temperatures in the 35-43°C/95-110°F range.

**Table 1: Columbia basin weather, WY 2021**

<b>Location</b>	<b>Temperature Columbia Basin above The Dalles  Departure from the 1981-2010 average (°C / °F)</b>	<b>Precipitation Columbia River above Grand Coulee  Percent of the 1981-2010 average (%)</b>	<b>Precipitation Snake River above Ice Harbor  Percent of the 1981- 2010 average (%)</b>	<b>Precipitation Columbia River above The Dalles  Percent of the 1981-2010 average (%)</b>
<b>October 2020</b>	+0.3 / +0.5	147%	80%	116%
<b>November 2020</b>	+0.4 / +0.7	96%	94%	98%
<b>December 2020</b>	+1.8 / +3.3	69%	44%	57%
<b>January 2021</b>	+1.5 / +2.7	75%	67%	73%
<b>February 2021</b>	-2.1 / -3.8	91%	116%	109%
<b>March 2021</b>	-0.2 / -0.3	38%	34%	32%
<b>April 2021</b>	+0.5 / +0.9	43%	30%	32%
<b>May 2021</b>	+0.4 / +0.8	74%	49%	55%
<b>June 2021</b>	+5.1 / +9.2	46%	30%	39%
<b>July 2021</b>	+4.7 / +8.5	18%	81%	37%
<b>August 2021</b>	+0.6 / +1.1	135%	131%	114%
<b>September 2021</b>	+0.9 / +1.6	93%	66%	94%
<b>Water Year 2021</b>	<b>+1.2 / +2.2</b>	<b>77%</b>	<b>63%</b>	<b>70%</b>

Basin average temperature departures and precipitation percent-of-normal (1981-2010) from NOAA/National Weather Service [https://www.nwrfc.noaa.gov/water\\_supply/wy\\_summary/wy\\_summary.php?tab=5 - tabs-5](https://www.nwrfc.noaa.gov/water_supply/wy_summary/wy_summary.php?tab=5 - tabs-5), Northwest River Forecast Center.

## **Water Supply**

With generally cool and wet weather over the fall and winter, by 01 March 2021 snowpack had climbed to 109 percent of normal across the Columbia Basin, with Canadian snowpacks at 111 percent of normal. However, even with favorable snow conditions, water supply forecasts were slightly below average heading into March 2021 as most of the fall and winter snows fell on rather dry soils left over from the warm and dry summer of 2020. Snowpack building ceased early in the year due to the aforementioned upper-level ridge. The combination of an uneven snowpack distribution and uneven rate-of-warming led to very different spring runoff profiles. In the Snake Basin, where snowpacks were well below average by mid-April 2021, unregulated flows remained below average for much of the spring. The lower Snake River projects peaked twice as progressively hotter weather arrived in May 2021, and then rapidly declined to near record lows by July 2021.

Meanwhile in the upper Columbia Basin, a cool spring and near average snowpack supported a much more normal runoff pattern, with a slow unregulated flow increase following the long-term average as measured at Grand Coulee. The peak of the runoff

occurred slightly later than usual in this part of the basin, with a round of warmth and some rainfall supporting a flow spike on 2-4 June 2021. An unusually high, late season runoff event occurred in late June - not from precipitation, but from record heat melting the remaining snowpack as well as some of the glacial mass above Mica, BC.

Unregulated flows provide a general perspective on the water supply from rainfall or snowmelt for that month or year. Table 2 provides WY 2021 average monthly unregulated streamflow and the percentage of the 1981-2010 average monthly flows for the Snake River at Lower Granite and Columbia River at The Dalles. After October, all monthly average flows were below average. Most notable, flows in June and July at Lower Granite were 56 and 42 percent of average. April-August runoff volume, measured at Lower Granite and The Dalles were 66 and 82 percent, respectively. The average monthly unregulated flow was greatest in May at Lower Granite Dam and June at The Dalles Dam.

**Table 2: Snake and Columbia River average unregulated flows in WY 2021<sup>5</sup>**

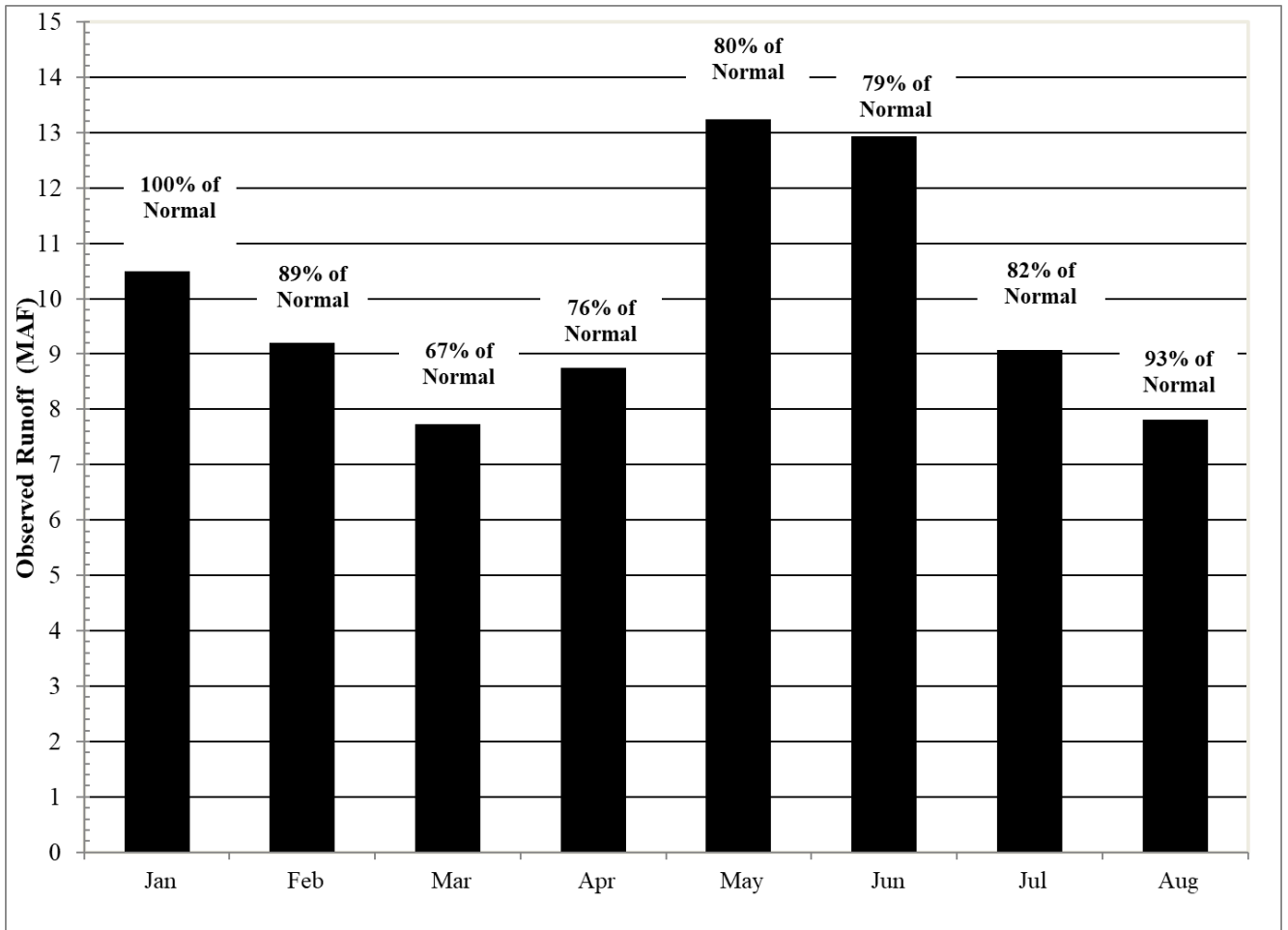
	<b>Snake River at Lower Granite Unregulated Flow (kcfs)</b>	<b>Snake River at Lower Granite % of Average</b>	<b>Columbia River at The Dalles Unregulated Flow (kcfs)</b>	<b>Columbia River at The Dalles % of Average</b>
October, 2020	22.66	98	86.47	105
November, 2020	23.48	87	88.98	94
December, 2020	21.24	74	73.78	81
January, 2021	25.46	79	91.14	93
February, 2021	23.57	58	80.72	70
March, 2021	38.90	71	100.27	68
April, 2021	54.01	70	169.06	73
May, 2021	89.36	79	360.95	88
June, 2021	56.97	56	393.56	90
July, 2021	15.70	42	167.24	71
August, 2021	13.43	67	91.16	73
September, 2021	14.84	74	73.51	85
<b>Oct-Sep Average</b>	<b>33.3</b>	<b>70%</b>	<b>148.3</b>	<b>82%</b>
<b>Apr-Aug Average</b>	<b>45.8</b>	<b>66%</b>	<b>235.8</b>	<b>82%</b>

Note: Unregulated Flows exclude the effects of regulation provided by storage reservoirs. Runoff average period: 1981-2010.

## **Reservoir Operation**

Generally, reservoir operation objectives include reaching the upper rule curve elevation on or about April 10 at the U.S. storage projects; refill on, or about June 30; and drafting reservoirs to summer draft limits. The observed runoff at The Dalles was below average throughout the fish passage season (Figure 1).

<sup>5</sup> From 2020 National Weather Service Runoff Processor.



**Figure 1: Observed monthly runoff at The Dalles**

On the lower Columbia River as measured at Bonneville Dam, daily average total river flow from April 1 through August 31 ranged from 104 to 298 kcfs, averaging 174 kcfs and peaking on June 6. A hydrograph for Bonneville Dam representing spill, generation, and miscellaneous flows (summing to total project flow in kcfs) is shown in Figure 2.

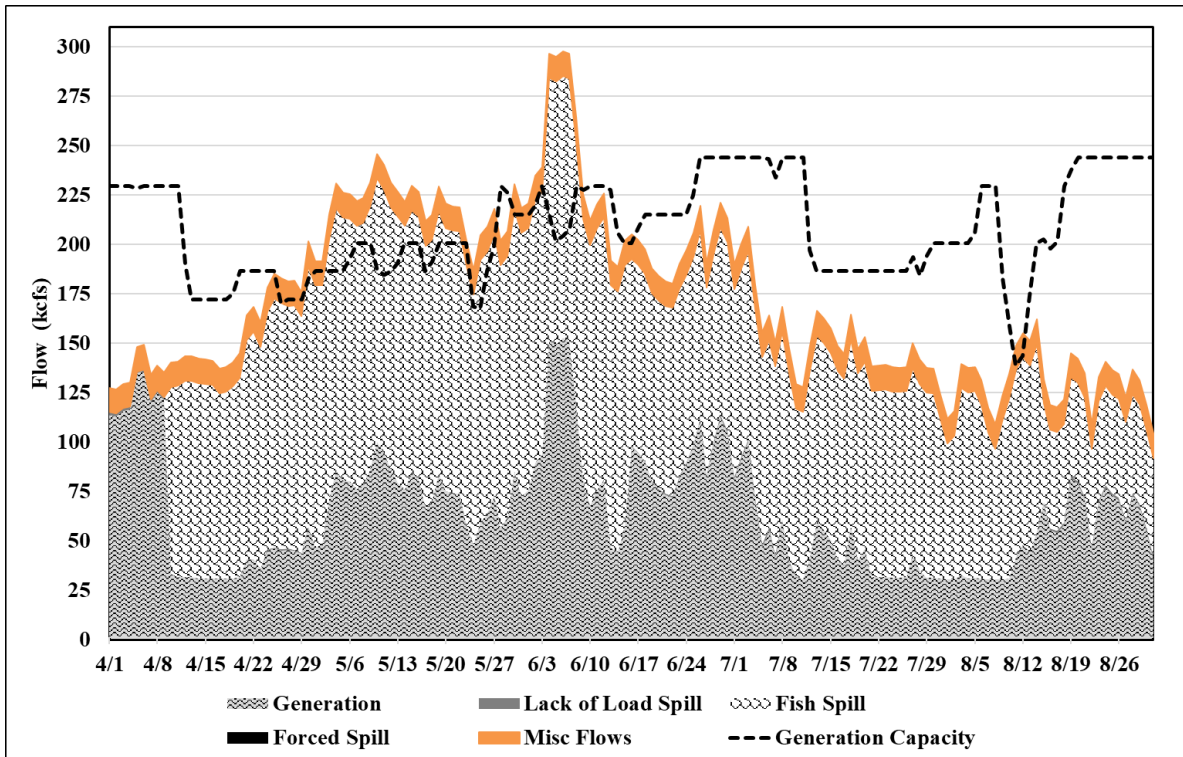


Figure 2: 2021 Bonneville daily project generation flow and spill.

On the lower Snake River as measured at Ice Harbor Dam, daily average total river flow from April 1 through August 31 ranged from 16 to 92 kcfs, averaging 45 kcfs and peaking on June 5 (Figure 3). Hydrographs for the remaining lower Snake and Columbia projects are shown in Appendix C.

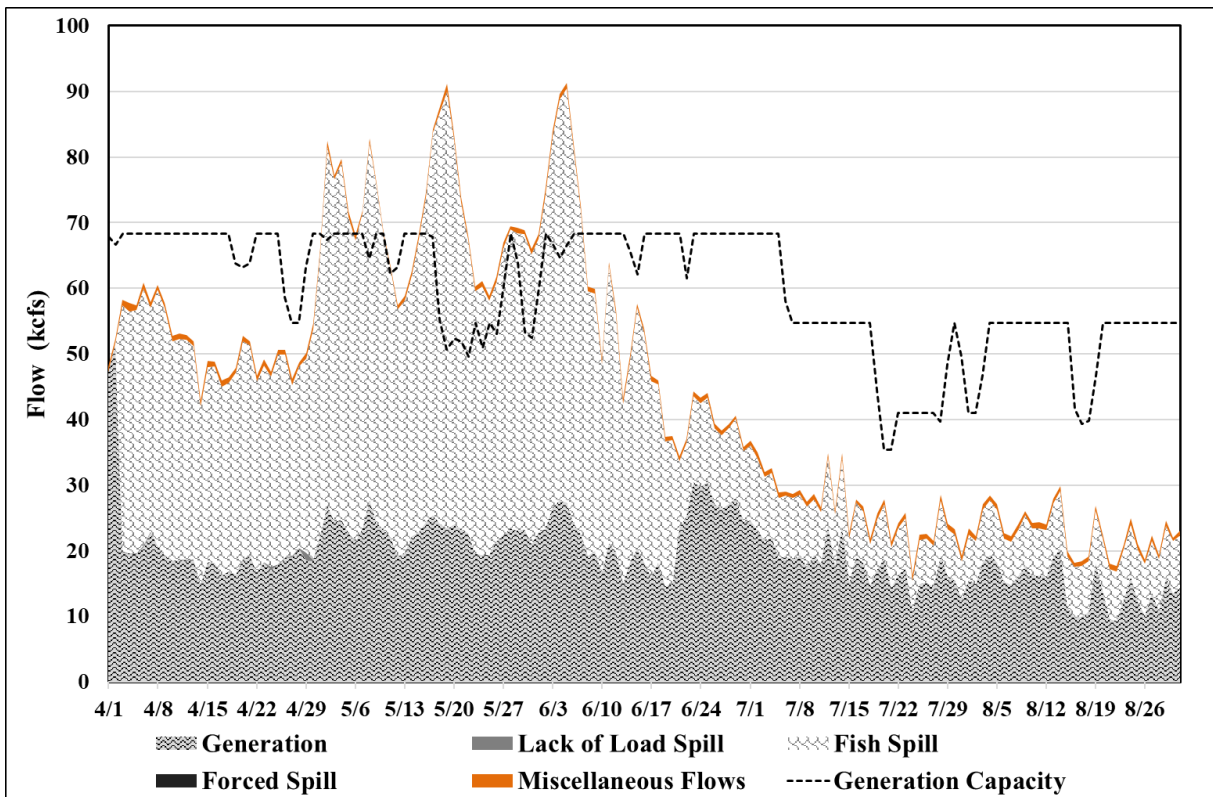


Figure 3: 2021 Ice Harbor daily project generation flow and spill.

## Flood Risk Management

The Columbia River Basin storage projects were operated to their specified flood risk management requirements based on the information available during the season. WY 2021 resulted in a relatively quiet flood risk management season due to below average seasonal volumes. The unregulated peak flow during the freshet (based on the Corps’ ResSim program output) at The Dalles was 465.3 kcfs, occurring on June 6, with a regulated daily peak flow of 286.2 kcfs occurring on June 6.

## Observed Flows above 7Q10

Daily average flows did not exceed the 7Q10 criteria at any of the lower Snake or lower Columbia River projects in 2021.

## Water Quality Monitoring

The Corps monitors the water quality of reservoir releases at the projects throughout the Columbia River Basin to manage fish passage spill operations at the fish passage projects in the lower Snake and lower Columbia rivers, as well as to manage system-wide water quality. The Corps monitors and tracks instances when TDG criteria are exceeded relative to state standards and applicable TDG modifications and criteria adjustments; and, when feasible, adjustments are made to meet the state criteria.

## **Fixed Monitoring Stations (FMS)**

TDG and water temperature are monitored throughout the Columbia River Basin via the FMS gauges. There are a total of 43 FMSs in the U.S. portion of the Columbia River Basin and 28 are operated by the Corps. Reclamation, and Chelan and Grant County Public Utility Districts (PUDs) each operate four stations. Three stations are operated by the Douglas County PUD. The Corps' Portland, Seattle, and Walla Walla districts operate and maintain the FMSs in the Columbia and lower Snake River basins. Portland District is responsible for eight FMSs on the lower Columbia River from John Day Dam to Camas/Washougal. The Seattle District is responsible for two FMSs in the upper Columbia Basin at Chief Joseph Dam. Walla Walla District is responsible for 15 FMSs in the lower Snake River and Clearwater River basins, and at McNary Dam on the Columbia River. Appendix A contains detailed information on the Corps' FMS system and a map of their locations.

## **TDG Monitoring Plan**

The monitoring performed by the Corps is part of a larger interagency water quality monitoring system described in the TDG Monitoring Plan that includes the Reclamation and the Washington PUD monitoring systems (as conducted by Douglas County PUD, Chelan County PUD, and Grant County PUD). The TDG Monitoring Plan summarizes the Corps' roles and responsibilities with TDG and temperature monitoring and identifies channels of communications with other cooperating agencies and interested parties. See <https://www.nwd.usace.army.mil/CRWM/Water-Quality/> for the most recent version.

## **Quality Assurance/Quality Control on Fixed Monitoring Stations**

The NOAA Fisheries 2020 BiOp, section 2.17.4.1(D), calls for the monitoring of TDG, specifically:

“The Action Agencies shall monitor TDG (including Grand Coulee, Chief Joseph, and Dworshak Dams, and the lower Snake and lower Columbia River dams) and associated biological impacts in the lower Snake and Columbia rivers in coordination with the mid-Columbia Public Utility Districts. This program will be developed in coordination with NMFS and relevant agencies or partners, and documented in the Water Quality Plan when periodically updated. A TDG monitoring plan will specify monitoring locations, sampling methodologies, calibration and maintenance of monitoring equipment, QA/QC, data collection and reporting, and archival storage in the Corps' online database. “

The Corps' districts operate the FMSs according to the TDG Monitoring Plan and prepare annual performance reports for the FMS operation. The 2021 reports are included as Appendices E, F, and G. Highlights from these reports are provided below.

## **Seattle District Quality Assurance/Quality Control**

Seattle District maintains and operates the forebay and tailwater TDG FMSs at Chief Joseph Dam. The highlights of the Seattle District QA/QC report are:

- Data completeness for TDG data received was 75.6 percent at the forebay station (CHJ) and 97.7 percent at the tailwater station (CHQW). Data completeness for temperature data received was 75.4 percent at station CHJ and 96.7 percent at station CHQW. Missing TDG and temperature data at both stations were largely due to DCP malfunctions and programming problems.
- For TDG data, at the forebay (CHJ) station a total of 2 hours were rejected due to slow probe response time after recalibration. At the tailwater station (CHQW) a total of 2 hours were rejected due to slow probe response time after recalibration. No temperature data was rejected at stations CHJ and CHQW.
- Laboratory calibration data were good and within 0.1°C for temperature and 1 percent saturation for TDG. Field calibration data were good and generally within 1mm Hg of the secondary standard barometer, 0.1°C of the secondary standard thermometer, and 1 percent saturation of the secondary standard TDG instrument.
- The TDG sensors were removed from the field after 2 weeks of deployment and calibrated in the laboratory.
- A total of 20 out of 21 (95%) in-situ field checks of total-dissolved-gas sensors with a secondary standard were within  $\pm 2$  percent after 2 weeks of deployment in the river.
- A total of 21 out of 21 (100%) in-situ field checks of barometric pressure were within  $\pm 2$  mm Hg of a secondary standard, and 21 out of 21 (100%) water temperature field checks were all within  $\pm 0.2^\circ\text{C}$ .

A detailed QA/QC report on the Seattle District gauges can be found in Appendix E.

## **Walla Walla District Quality Assurance/Quality Control**

Walla Walla District is responsible for maintaining and operating the forebay and tailwater TDG FMS stations at Dworshak, Lower Granite, Little Goose, Lower Monumental, Ice Harbor, and McNary dams. This work is performed through a cooperative agreement with the U.S. Geological Survey (USGS) Kennewick office. The highlights of the Walla Walla District QA/QC report include:

- Data completeness for the combined barometric pressure, TDG, and temperature data received averaged 99.3 percent for the 14 monitoring sites used in 2021.
- The TDG data received from the individual sites ranged from 87.6 percent to 100.00 percent complete.
- The TDG sensors from the 14 FMSs were removed from the field and calibrated in the laboratory every three weeks from April 2021 through August 2021. From September 2020 through March 2021, the six annual FMSs were calibrated at four-week intervals.

- The sensor pre-deployment check had calculated mean ambient pressure, ambient pressure plus 300 mmHg, and temperature differences of -0.48 mmHg, -0.45 mmHg, and 0.03 °C, respectively. The sensor post-deployment check revealed mean ambient pressure, ambient pressure plus 100 mmHg, and temperature differences of 0.10 mmHg, -2.04 mmHg, and 0.00 °C, respectively.
- The calculated median values for the 157 *in-situ* field checks with the replacement probes were:
  - TDG; -0.1 percent with minimum and maximum station medians of 0.00 percent.
  - BP; 0.00 mmHg with station medians ranging from -0.20 to 0.10 mmHg.
  - Water temperature; -0.01 °C with station median values ranging from -0.04 °C to 0.03 °C.
- Station repairs and maintenance were also completed during the 2021 water year:
- The data collection and transmission equipment at Ice Harbor tailwater (IDSW) was moved from the Coast Guard navigation marker to a shore-based station.
- Rebuild of the Lower Monumental tailwater station (LMNW) that was damaged by fire in 2019 was completed.
- Sediment build-up at four of the deployment pipes was removed with compressed air.

A detailed QA/QC report on the Walla Walla District gauges can be found in Appendix F.

### **Portland District Quality Assurance/Quality Control**

Portland District maintains and operates the forebay and tailwater gauges at John Day, The Dalles and Bonneville dams. This work is performed through a contract with the Portland, Oregon Office of the USGS. The highlights of the Portland District QA/QC report include:

- Data received in real-time from the seven individual monitoring sites ranged from 91.7 percent (at Warrendale) to 99.8 percent complete.
- Criteria for data completeness (95 percent) were met at all monitoring stations, except for Warrendale. Equipment was removed at the site from February 2 to 26, 2021. The shed housing the equipment was damaged beyond repair and shipping of a replacement was delayed due to extreme winter weather. Excluding that period, data completeness was greater than 99 percent at the site.
- After approximately three to four weeks of deployment in the river, 74 of 76 TDG sensor field checks were within  $\pm 1.0$  percent saturation of a secondary standard sensor. One of the two field checks that failed the guideline was due to a ruptured TDG membrane. The reason for the other instance (-1.3 percent saturation) was unclear, but it was not due to a ruptured membrane and no data were deleted because of the difference.
- One of 73 barometric pressure field checks was greater than  $\pm 1$  mmHg of a primary standard, ranging from -15.7 to +1.0 mmHg. The difference of -15.7 mmHg was due to a malfunctioning barometer that recorded intermittent erroneous values for several days before it was replaced.

- All 73 water-temperature field checks were within  $\pm 0.2$  °C of a secondary standard, ranging from -0.13 to + 0.04 °C.
- All 71 TDG sensor laboratory checks that were performed after field deployment were within  $\pm 0.5$  percent saturation of a primary standard at ambient air pressure and at ambient air pressure plus 300 mmHg.
- During each scheduled site visit, the TDG sensors were field checked, removed and replaced with recently calibrated sensors, and brought to the lab for calibration checks. The three year-round tailwater sites were visited monthly from October 2020 through March 2021. The Cascade Island (Bonneville Dam tailwater) site was installed in March 2021 and the four operational sites were then visited every three weeks. The installation of the three seasonal forebay sites was deferred until May 2021 when they were added to the three-week visitation schedule.

A detailed QA/QC report on the Portland District gauges can be found in Appendix G.

## Fish Passage Spill Program

Operation of the federal Columbia River System projects to meet multiple authorized purposes can result in exceedances of percent TDG state water quality standards. This section provides detailed information on the implementation of fish passage spill as well as forced spill (e.g., lack of turbine, lack of load, transmission constraints, etc.).

## Fish Passage Spill Operations

The 2021 FOP ([http://pweb.crohms.org/tmt/documents/fpp/2021/final/FPP21\\_AppE\\_03-31-21.pdf](http://pweb.crohms.org/tmt/documents/fpp/2021/final/FPP21_AppE_03-31-21.pdf)) provides detailed information on spill and transport operations at the Corps’ four lower Snake River and four lower Columbia River projects. Fish passage spill quantity can be a specified level or a spill rate estimated to result in TDG target, referred to as the “gas cap spill”. The maximum project spill level that meets but does not exceed the gas cap is referred to as the spill cap. 2021 target spill operations for spring and summer are summarized in Table 3 and Table 4, respectively.

**Table 3: Summary of 2021 spring target spill levels at lower Snake River (April 3 – June 20) and lower Columbia River (April 10 – June 15) projects.**

<b>PROJECT</b>	<b>SPRING FLEX SPILL (16 hours per day)<sup>A, B, C, E</sup></b>	<b>SPRING PERFORMANCE STANDARD SPILL (8 hours per day)<sup>B, D, E</sup></b>
Lower Granite <sup>E</sup>	125% Gas Cap	20 kefs
Little Goose <sup>F, G</sup>	125% Gas Cap	30%
Lower Monumental <sup>E</sup>	125% Gas Cap (uniform spill pattern)	30 kefs (uniform spill pattern)
Ice Harbor	125% Gas Cap	30%
McNary	125% Gas Cap	48%
John Day	120% TDG target	32%

PROJECT	SPRING FLEX SPILL (16 hours per day) <sup>A, B, C, E</sup>	SPRING PERFORMANCE STANDARD SPILL (8 hours per day) <sup>B, D, E</sup>
The Dalles <sup>H</sup>	40%	40%
Bonneville <sup>I</sup>	125% Gas Cap	100 kcfs

A. If deleterious impacts of the proposed spill operations are observed in-season, existing adaptive management processes may be employed to address the cause of the impacts.

B. Spill may be temporarily reduced at any project to ensure navigation safety or transmission reliability. In order to operate consistently with state water quality standards, spill may also be reduced if observed Gas Bubble Trauma (GBT) levels exceed those identified in state water quality standards or if minimum sample sizes for salmonid or native, non-salmonid fish are not met (See [WASH. ADMIN. CODE § 173-201A-200\(I\)\(f\)\(ii\)\(B\)\(III\)](#) and *Order Approving a Modification to the Oregon's Water Quality Standard for Total Dissolved Gas in the Columbia River Mainstem*, page 5).

C. 125% Gas Cap spill is spill to the maximum level that meets, but does not exceed, the TDG criteria allowed under state laws. This includes a criterion for not exceeding 126% TDG for the average of the two greatest hourly values within a day.

D. The 8 hours of performance standard spill may occur with some flexibility (except for Lower Granite, Little Goose, and Lower Monumental operations described in the footnotes below). Other than at The Dalles Dam, performance standard spill occurs in either a single 8-hour block or two separate blocks per calendar day. Performance standard spill is not to be implemented between 2200-0300 hours. No ponding above current MOP assumptions except as noted below.

E. If adult passage delays are observed at Lower Granite or Lower Monumental dams, the Corps may implement performance standard spill at these projects starting in the morning (AM) and continuing for at least 4 consecutive hours to target hours of peak adult passage. If performance standard spill is not able to be implemented due to lack of load conditions at the targeted start times, performance standard spill will begin as soon as practicable during morning hours and continue for at least 4 consecutive hours. Implementation of this modification will trigger in-season re-evaluation of options to balance power principle consistent with existing analysis in the CRSO EIS and 2020 BiOps.

F. Little Goose Exception One - Within 1 business day of a cumulative total of 25 adult spring Chinook salmon (not including jacks) passing Lower Monumental Dam, the Corps will implement performance standard spill at Little Goose Dam for 8 consecutive AM hours (April 3-15 starting at 0500 hours; April 16-June 20 starting at 0400 hours) to target hours of peak adult passage. If performance standard spill is not able to be implemented due to lack of load conditions at the targeted start times, performance standard spill will begin as soon as practicable during morning hours and continue for up to 8 consecutive hours consistent with the adaptive management principles of the 2020 BiOps.

G. Little Goose Exception Two - During periods of lack of capacity, lack of load conditions, implementing performance standard spill for 8 consecutive hours as described in footnote F may result in storing additional inflow that exceeds hydraulic capacity in the forebay above MOP. If it is necessary to pond water to achieve the 8-hour block of 30% spill during high inflow, water stored above MOP should be drafted out over the remaining hours by increasing spill to pass inflow from 1200-1600 hours (or 1300-1700 hours from April 3-15), then increasing spill as necessary from 1600-0400 (or 1700-0500 hours from April 3-15) to draft the pool back to MOP. If it is forecasted that the drafting spill will result in exceeding 130% TDG in the tailrace, all 16 hours will be used to return the pool to MOP.

H. Fish passage spill at The Dalles Dam should be limited to spillbays 1-8 unless river flow exceeds 350 kcfs, then spill outside the spillwall is permitted. TDG levels in The Dalles tailrace may fluctuate up to 125% TDG prior to reducing spill at upstream projects or reducing spill below 40% at The Dalles.

I. Fish passage spill at Bonneville Dam should not exceed 150 kcfs due to erosion concerns.

**Table 4: Summary of 2021 summer target spill levels at lower Snake River and lower Columbia River projects.**

<b>PROJECT</b>	<b>SUMMER SPILL<sup>A</sup> (June 21/16 – August 14) (24 hrs/day)</b>	<b>SUMMER SPILL<sup>A</sup> (August 15 – August 31) (24 hrs/day)</b>
Lower Granite <sup>B</sup>	18 kcfs	SW flow or ~7 kcfs spill
Little Goose <sup>B</sup>	30%	SW flow or ~7 kcfs spill
Lower Monumental <sup>B</sup>	17 kcfs	SW flow or ~7 kcfs spill
Ice Harbor <sup>B</sup>	30%	SW flow or ~8.5 kcfs spill
McNary	57%	20 kcfs
John Day	35%	20 kcfs
The Dalles	40%	30%
Bonneville	95 kcfs	50 kcfs

A. Spill may be temporarily reduced below the FOP target summer spill level at any project if necessary to ensure navigation safety or transmission reliability, or to avoid exceeding State TDG standards.

B. Summer spill from August 15-August 31 may be through the SW or through conventional spillbays using the appropriate FPP spill pattern for each project. The SWs will be operated consistent with the SW operational criteria in the FPP.

The Corps tracks the rate of spill that occurs at the eight fish passage dams as part of the FOP Implementation Report requirements. Fish passage spill quantities are shown in monthly graphs of the flow, FOP spill, and generation for April through August. These monthly graphs are included in the monthly FOP implementation reports ([https://pweb.crohms.org/tmt/documents/FOP\\_Implementation\\_Reports/Older/](https://pweb.crohms.org/tmt/documents/FOP_Implementation_Reports/Older/)).

The daily flow, FOP spill, and generation rates for April through August are further summarized in Tables C-3 through C-10 of Appendix C. The flow, generation, actual and FOP fish passage spill for the 2021 spill season at each dam is graphed for the entire April through August spill season and included in Appendix C as Figures C-1 through C-8.

In addition to spring and summer spill for juvenile fish, surface spill was provided for adult steelhead passage at Lower Granite, Little Goose, Lower Monumental, Ice Harbor, and McNary dams from October 1 to November 15 and again from March 1 to April 2 (April 9 at McNary Dam).

## Long-Term Turbine Outages

Unit outages can affect the spill rate at the dams by causing additional forced spill. Table 5 summarizes the long-term unit outages during the 2021 fish passage season. Not all outages result in spill or elevated TDG levels.

**Table 5: 2021 long-term outages**

<b>Project</b>	<b>Units</b>	<b>Start Date</b>	<b>End Date</b>	<b>Reason</b>
<b>Lower Granite</b>	06	3/1/2021	4/8/2021	Replace SU6 and Gov oil pumps on Unit 6

<b>Project</b>	<b>Units</b>	<b>Start Date</b>	<b>End Date</b>	<b>Reason</b>
<b>Lower Granite</b>	06	7/26/2021	9/23/2021	6-year overhaul
<b>Little Goose</b>	05	10/23/2019	Ongoing	Forced outage due to excessive turbine guide runout
<b>Little Goose</b>	01	11/30/2020	4/15/2021	Unit annual outage
<b>Little Goose</b>	06	3/18/2021	Ongoing	Forced outage due to powerhouse bank #2 outage
<b>Little Goose</b>	03	7/26/2021	9/16/2021	Unit annual & OPTO-22 install
<b>Lower Monumental</b>	02	9/28/2020	Ongoing	Non-routine repair of turbine runner hub gasket sealing surface and turbine to generator shaft O-ring replacement
<b>Lower Monumental</b>	04	7/6/2021	9/8/2021	Unit annual outage
<b>Ice Harbor</b>	03	10/31/2019	6/1/2022	Turbine replacement
<b>Ice Harbor</b>	06	7/19/2021	8/19/2021	Annual maintenance/ oil replacement
<b>Grand Coulee</b>	22	10/31/2019	Ongoing	Major overhaul
<b>Grand Coulee</b>	08	1/31/2020	Ongoing	Forced outage due to differential L/O
<b>Grand Coulee</b>	07	9/2/2020	Ongoing	Forced outage due to possible stator ground
<b>Grand Coulee</b>	24	2/20/2021	Ongoing	Sexennial maintenance
<b>Chief Joseph</b>	17-20	4/5/2021	5/21/2021	500kV line maintenance
<b>McNary</b>	05	12/7/2020	8/18/2021	Thrust bearing spring bed rehabilitation
<b>McNary</b>	02	6/7/2021	8/19/2021	Main unit overhaul
<b>McNary</b>	01, 02	7/12/2021	8/19/2021	BPA transmission outage of powerhouse line #1
<b>John Day</b>	07	10/23/2019	Ongoing	Forced outage due to CO <sub>2</sub> discharge
<b>John Day</b>	16	2/22/2021	Ongoing	5-Year Overhaul
<b>John Day</b>	05-08	3/15/2021	6/10/2021	Grid MOD work
<b>John Day</b>	12	4/8/2021	Ongoing	Turbine rehab
<b>John Day</b>	09-12	6/11/2021	8/16/2021	500KV line outage for grid mod. and line reconductor
<b>John Day</b>	13	7/6/2021	Ongoing	Unit annual outage
<b>The Dalles</b>	19, 20	10/31/2019	Ongoing	Forced outage due to gassing on T-10 transformer
<b>The Dalles</b>	22	3/1/2021	5/17/2021	Overhaul & Top Plate Cover
<b>The Dalles</b>	12	4/12/2021	Ongoing	Unit annual outage
<b>The Dalles</b>	07	6/1/2021	8/5/2021	Overhaul & T4 Doble testing
<b>The Dalles</b>	21	7/12/2021	9/20/2021	Intake Gantry crane rail replacement
<b>The Dalles</b>	22	7/12/2021	9/20/2021	Intake Gantry crane rail replacement
<b>Bonneville</b>	15	3/1/2021	4/19/2021	FGE work
<b>Bonneville</b>	16	3/15/2021	5/6/2021	4-year overhaul
<b>Bonneville</b>	10	4/12/2021	6/25/2021	Annual overhaul/PT Installation
<b>Bonneville</b>	09	4/12/2021	6/25/2021	5-year overhaul/install PTs
<b>Bonneville</b>	07-10	4/12/2021	5/27/2021	Station service work
<b>Bonneville</b>	05	6/14/2021	8/12/2021	5-year overhaul
<b>Bonneville</b>	05, 06	7/12/2021	8/12/2021	Transformer maintenance
<b>Bonneville</b>	06	7/12/2021	8/12/2021	Annual overhaul

## TDG Exceedances of the WQS

Exceedance reporting in this section is consistent with the Corps' TDG Management Operations described in previous sections of this document.

### 125% (Spring) and 115%/120% (Summer) TDG evaluation

Table 6 provides a summary of TDG exceedances and data quality events during the 2021 spill season for the lower Columbia and lower Snake projects except when flows are greater than the 7Q10. There was a total of 27 gauge days in 2021 in which the TDG levels were above the applicable TDG criteria and 27 gauge days in which there was a data quality event and TDG could not be evaluated. TDG exceedances are evaluated by day in Appendix D.

**Table 6: Summary of TDG exceedances and data quality events**

<b>Fixed Monitoring Stations</b>	<b>Exceedances</b>	<b>Data Quality Events</b>
Lower Granite Forebay (LWG)*	0	0
Lower Granite Tailwater (LGNW)	0	12
Little Goose Forebay (LGSA)*	2	2
Little Goose Tailwater (LGSW)	0	0
Lower Monumental Forebay (LMNA)*	10	1
Lower Monumental Tailwater (LMNW)	0	9
Ice Harbor Forebay (IHRA)*	9	0
Ice Harbor Tailwater (IDSW)	0	2
McNary Forebay (MCNA)*	0	0
McNary Tailwater (MCPW)	0	0
John Day Forebay (JDY)*	1	0
John Day Tailwater (JHAW)	0	0
The Dalles Forebay (TDA)*	0	0
The Dalles Tailwater (TDDO)	0	1
Bonneville Forebay (BON)*	5	0
Bonneville Tailwater (CCIW)	0	0
<b>Total</b>	<b>27</b>	<b>27</b>

\* Evaluated during summer spill only

### Recurring TDG Exceedances

In 2021, three locations had more than two TDG exceedances. All three locations were in the project forebay, and the exceedances occurred during summer spill, when the forebay WQS is 115% TDG.

- The Lower Monumental forebay gauge had 10 exceedances: 6 during the transition from spring to summer spill and 4 due to model and forecast uncertainties.
- The Ice Harbor forebay gauge had 9 exceedances: 6 during the transition from spring to summer spill and 3 due to model and forecast uncertainties.

- The Bonneville forebay gauge had 5 exceedances, all due to model and forecast uncertainties.

## Categories of TDG Exceedances

The Corps tracked the daily TDG exceedance types for the forebay and tailwater of each of the Corps’ federal Columbia River projects during the 2021 spill season. Each type of TDG exceedance represents conditions that cause daily average percent TDG to exceed the applicable WQS. Exceedance tracking results are summarized in Table 7. Daily details by dam can be found in Appendix D. The daily TDG exceedance type designation given for each occurrence is based on the Corps’ determination of causation.

**Table 7: TDG exceedance type summary**

<b>TDG Exceedance Type</b>	<b>Definition</b>	<b>Quantity</b>
<b>Forced Spill Exceedance</b>	TDG WQS exceedance due to spill above the FOP spill level.	0
<b>Mechanical Exceedance</b>	TDG WQS exceedance due to the operation or mechanical failure of non-generating equipment.	0
<b>Uncertainty Exceedance</b>	TDG WQS exceedance due to uncertainties when using best professional judgment, SYSTDG model and forecasts.	13
<b>Transition Exceedance</b>	TDG WQS exceedance due to change in the spill operation and WQS from spring to summer.	14

The two primary contributors of TDG exceedances in 2021 were the transition from spring to summer spill and uncertainty when using best professional judgment, and forecasts. These uncertainties resulted in unpredicted high resultant TDG levels despite compliance with *Procedure for Setting 2021 Spill Caps*.

## Oregon and Washington maximum two-hour criteria

During the 2021 spill season, there were no days when TDG readings exceeded either the Washington two-hour standard of 126% TDG or the Oregon two-hour standard of 127% TDG at the tailwater gauges during the spring (Appendix D). There were no days during summer spill in which the two-hour standard of 125% TDG was exceeded.

## WQS exceedances outside of juvenile fish passage spill

There are occasional exceedances of the 110% TDG criteria during periods when juvenile fish passage spill is not occurring, typically September through March. There are also occasions when there is missing data. TDG values are reported here: [https://pweb.crohms.org/ftppub/water\\_quality/12hr/](https://pweb.crohms.org/ftppub/water_quality/12hr/)

Outside the juvenile fish passage spill period in WY 2021, the TDG exceedances are typically due to forced spill from high flows and high TDG levels from fish ladders. The following TDG exceedances are notable either for duration or spatial extent:

- The tailwater gauge at Bonneville Dam, CCIW, measured values exceeding 110% TDG in March and April 2021. Fish ladders allow for adult upstream passage. Bonneville fish ladders have a combined flow of 4.7 kcfs and can produce TDG levels as high as 135% TDG. During juvenile fish passage season, the TDG generated by the fish ladders is diluted with flow from the spillway. The location of CCIW is such that it is measuring the fish ladder discharges without any mixing with powerhouse flow. The Warrendale gauge, WRNO, is located approximately six miles downstream and measures TDG that has been mixed with powerhouse flow. WRNO did not exceed the TDG criteria during this period.

### Fall and early spring spill for adult steelhead

Per the 2020 Biological Opinion, surface-oriented spill is conducted via the spillway weir, for adult steelhead that overshoot and then migrate back downstream through McNary Dam and the lower Snake River dams from October 1 until November 15 and from March 1 to March 30. This operation occurred three times per week on non-consecutive days for four hours each morning. Table 8 lists the exceedances of the WQS during spill for adult steelhead.

**Table 8: Exceedances of the 110% WQS, Data Quality Events, and maximum TDG observed during fall and early spring spill for adult steelhead**

<b>Fixed Monitoring Stations</b>	<b>Exceedances*</b>	<b>Data Quality Events</b>	<b>Maximum TDG</b>
<b>LGNW</b>	5	0	116
<b>LGSW</b>	0	0	108
<b>LMNW</b>	18	1	113
<b>IDSW</b>	0	1	110
<b>MCPW</b>	0	1	109
<b>Total</b>	<b>23</b>	<b>3</b>	

\* Includes exceedances only during spill specified for steelhead, and does not include exceedances due to forced spill.

### Gas Bubble Trauma Monitoring

As part of the TDG monitoring program, the NOAA Fisheries 2020 BiOp, section 2.17.4.1(D), specifies that the TDG monitoring program will include:

“...a biological smolt monitoring component to assess GBT symptoms in smolts at selected smolt monitoring locations, especially between April 3 and June 20 when the flexible spring spill operation is being implemented. TDG pressure and percent saturation, water temperature, and barometric pressure must be sampled on at least an hourly basis. This information, and the results of biological monitoring shall be shared with resource agencies on a near real-time basis. This will reduce take by ensuring that incubating eggs and fry or migrating juvenile and adult salmon and steelhead are not exposed to TDG

levels higher than anticipated and that the effects of increased exposure to TDG are not more severe for juvenile and adult migrants than expected.”

The Fish Passage Center compiles a yearly report of Gas Bubble Trauma (GBT) monitoring results (Appendix H). The monitoring of juvenile salmonids in 2021 for GBT was conducted at six Columbia and Snake River projects. Sampling occurred two days per week at the Columbia River sites and one day a week at each of the Snake River sites during 2021 fish passage spill operations. The goal of the GBT monitoring program was to sample 100 salmonids during each day of sampling at each site, limited to Chinook and steelhead. The eyes and unpaired fins of specimens were visually examined for the presence of bubble using magnification scopes. The GBT action criteria for spill curtailments is 15% of fish showing any signs of fin GBT, or 5% of the fish showing severe signs of fin GBT. Signs of fin GBT are deemed severe when  $\geq 26\%$  of an unpaired fin is covered with bubbled. Of the 11,016 juvenile salmonids examined, 164 had signs of GBT between April and August (see Appendix H, Table H-3).

For the first time in 2021, GBT monitoring of native resident non-salmonids (NRN) was conducted by the U.S. Geological Survey at three locations in the spring: below Ice Harbor, below McNary, and below Bonneville with a goal of collecting 100 samples per sampling day. Fish were collected at each location weekly (6 April to 17 June) during the spring spill period by backpack electrofishing and beach seining. Washington and Oregon state water quality agencies established minimum and target sample sizes for monitoring, and in all weeks the minimum sample size of 50 fish was met and in most weeks the target sample size of 100 fish was met. Collected fish were examined for GBT according to the criteria and protocol established for the regional smolt monitoring program (SMP). Overall, GBT incidence and severity rankings were low and did not exceed the thresholds that would have triggered changes to the spill program. Using SMP criteria, weekly GBT incidences ranged from 0 to 1.0% downstream from Bonneville Dam, 0 to 6.2% downstream from McNary Dam, and 0 to 1.9% downstream from Ice Harbor Dam. Except for one three-spined stickleback (*Gasterosteus aculeatus*) collected downstream of Bonneville Dam, the only NRN species that showed signs of GBT was sculpin spp. GBT was observed in sculpin in body locations other than the unpaired fins and eyes (i.e., SMP criteria). If GBT incidence in all areas on the fish (i.e., paired fins, unpaired fins, eyes, body) are combined, then weekly GBT incidence rates increase and range from 0 to 4.3% downstream from Bonneville Dam, 0 to 15.4% downstream from McNary Dam, and 0 to 4.7% downstream from Ice Harbor Dam. This illustrates the effect of using different criteria to determine the incidence of GBT in NRN fishes. It also shows how the proportion of a species in a sample that is more prone to show GBT can influence GBT incidence rate. On a number of occasions, incidental catch of subyearling fall Chinook salmon were examined for GBT downstream of Bonneville Dam but none showed any signs. The TDG was generally below 120% and never reached the 125% gas cap during the spring spill season, which may be why GBT incidence rates were so low as past research has shown that GBT signs in NRN fishes are relatively low below this TDG level (<https://www.cbfish.org/Document.mvc/Viewer/P186658>).