US Army Corps of Engineers®
Northwestern Division

2008 DISSOLVED GAS AND WATER TEMPERATURE MONITORING REPORT

COLUMBIA RIVER BASIN

The Dalles Forebay TDG Monitoring Site

Columbia Basin Water Management Division
Reservoir Control Center
Water Quality Unit

December 2008

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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)
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Fish Passage Center

2008 TOTAL DISSOLVED GAS AND WATER TEMPERATURE MONITORING COLUMBIA RIVER BASIN

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List of Acronyms

The following acronyms are used throughout this report.

AFEP-SRWG	Anadromous Fish Evaluation Program-Studies Review Work Group
BiOp	Biological Opinion
BPA	Bonneville Power Administration
Cfs	cubic feet per second
Corps	US Army Corps of Engineers
CRT	Columbia River Treaty
DQC	Data Quality Criteria
ESA	1973 Endangered Species Act
FCOP	Flood Control Operating Plan
FCRPS	Federal Columbia River Power System
FMS	fixed monitoring station
FPE	fish passage efficiency
FOP	Fish Operations Plan
FPIP	Fish Passage Implementation Plan
FPP	Fish Passage Plan
GBT	gas bubble trauma
IT	Implementation Team
Kcfs	thousand cubic feet per second
LCA	Libby Coordination Agreement
Maf	million acre-feet
MOP	minimum operating pool
NMFS	National Marine Fisheries Service (Now, NOAA Fisheries)
NOAA Fisheries	National Oceanic and Atmospheric Administration, Fisheries
NWF	National Wildlife Federation
NWPPC	Northwest Power Planning Council
ODEQ	Oregon Department of Environmental Quality
PUDs	Public Utility Districts
QA	quality assurance
QC	quality control
RO	regulating outlet
ROCASOD	Record of Consultation and Summary of Decision
ROD	Record of Decision
RPA	Reasonable and Prudent Alternative (from the Biological Opinion)
RSW	removable spillway weir
TDG	total dissolved gas
TMT	Technical Management Team
TMDLs	Total Maximum Daily Loads
TSW	top (or temporary) spillway weir

UPA	Updated Proposed Action
USF&WS	United States Fish and Wildlife Service
USBR	United States Bureau of Reclamation
VARQ	Variable Q, a variable flow associated with Libby flood control
WDOE	Washington Department of Ecology
WQS	Water Quality Standards
WQT	Water Quality Team
WY	water year

Terminology

The US Army Corps of Engineers (Corps) has noted different agencies applying various definitions to common terminology. The following are the Corps definitions, which are used throughout this report and the 2008 Water Management Plan.

Voluntary Spill: Passing water through a project spillway, or spill, to assist juvenile salmon and steelhead migration through the Federal Columbia River Power System (FCRPS). Voluntary spill is used to decrease the residence time of juvenile salmon and steelhead in the forebay of mainstem dams, which increases their survival through the lower Columbia and Snake rivers. Spill is also used at Dworshak Dam to provide additional water for flow augmentation and to improve temperature conditions in the lower Snake River. The amount of voluntary spill is adjusted so that the resulting TDG levels associated with spill are consistent with applicable State water quality standards.

The amount of voluntary spill in the lower Snake and Columbia rivers is influenced by the flow in the river, including augmentation activities provided by upstream projects. For example, the Canadian projects and Grand Coulee flow augmentation influences flow and spill in the lower Columbia River, and Dworshak and Hells Canyon releases influence flow and spill on the lower Snake River. The National Oceanographic and Atmospheric Administration, Fisheries (NOAA Fisheries) and United States Fish and Wildlife Service (USF&WS) Biological Opinions (BiOps) call for flow augmentation in the Columbia and Snake Rivers.

Involuntary Spill: Spill that results primarily from project and/or system operational limitations such that water cannot be stored. There are two primary causes of involuntary spill:

1. Hydrologic conditions result in flows which exceeding the hydraulic capacity of power generation facilities; and

2. Flow that exceeds the available power generation market, especially during light market hours at night and on weekends.

Other causes of involuntary spill include, passing debris, scheduled or unscheduled turbine unit outages of various durations, or any other operational and/or maintenance activities required to appropriately manage project facilities. For example, in managing for flood control, the project operators rely on the current water supply forecast; and if the actual streamflows are underestimated, there may too little space in the reservoirs to catch the inflows and must be spilled. In other instances, unusually high winter precipitation may force the operators to temporarily store water in the reservoirs above the flood control elevations, causing involuntary spill to occur later as the water is evacuated to get back to the reservoir flood control elevations.

Intertie Line Derating: The intertie line is the transmission system that transfers electricity between the Pacific Northwest and California. It is de-rated when its ability to transfer the electricity is decreased due to stability, thermal or environmental factors.

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

Lack of Load: There is a lack of customer need for power resulting in a lack of market for electricity generated.

TMT: The Technical Management Team is an interagency technical group responsible for making recommendations on dam and reservoir operations. This group is comprised of representatives from sovereign entities including five U.S. Federal agencies (Bonneville Power Administration (BPA), Bureau of Reclamation (BoR), Corps, NOAA Fisheries, and US Fish and Wildlife Service (USFWS)), four states (Idaho, Montana, Oregon, and Washington), and participating Tribes.

Part 1 Program Description

1.0 Introduction

This report describes the Corps' Columbia River Basin Water Quality Monitoring Program for 2008 and covers the lower Columbia and Snake River projects. The report was developed to meet the Corps' total dissolved gas (TDG) and temperature water quality program responsibilities and the objectives of the 2000 and 2004 NOAA Fisheries BiOps. The report provides information consistent with the TDG waiver issued by the state of Oregon and the criteria adjustment by the state of Washington. The report also includes additional requested technical information including flow and runoff conditions for the spill season, duration and volume of spill for fish passage versus spill for other reasons for each project, data from the physical and biological monitoring programs, including incidences of gas bubble trauma (GBT), description and results of any biological or physical studies of spillway structures and prototype fish passage devices to test spill at operational levels, and progress on implementing measures contained in the Lower Columbia and Lower Snake River TDG Total Maximum Daily Load (TMDL) documents. This information is used by the states in processing waivers or criteria adjustments to the state Water Quality Standards (WQS) for TDG.

The report focuses on the water quality monitoring of TDG and temperature at the 12 Corps dams in the Columbia River Basin (Bonneville, The Dalles, John Day, McNary, Chief Joseph, Ice Harbor, Lower Monumental, Little Goose, Lower Granite, Dworshak, Libby and Albeni Falls dams).

This document provides a detailed review of TDG and water temperature data. Appendix A provides a general overview of the monitoring system with information on the fixed monitoring stations (FMS). Appendix B provides the monitoring plan of action for 2008. The Fish Operations Plan (FOP) that was used as the guideline for 2008 spill season can be found as Appendix C. Appendix D provides reports on the Fish Operations Plan (FOP) spill operations for 2008. Appendix E contains the 2008 monthly court reports filed with the court during spill season. This appendix contains graphs of flow, spill and high 12-hour %TDG average along with variance tables. Appendix F provides summary tables of TDG levels and exceedance types. Appendix G provides a detailed evaluation of how well SYSTDG performed during the 2008 spill season. Appendix H provides graphs of hourly water temperature data. The Dworshak operations are summarized in Appendix I. Appendix J provides a review of the Quality Assurance/Quality Control (QA/QC) for the TDG and temperature monitoring gages at Lower Granite; Little Goose; Lower Monumental; Ice Harbor; and McNary dams Appendix K provides a review of the QA/QC for the TDG and temperature monitoring gages at John Day, The Dalles, Bonneville dams, and the Warrendale and Camas/Washougal sites Appendix L provides a review of the QA/QC for the TDG and temperature monitoring gages at Libby, Chief Joseph and Albeni Falls dams. The Fish Passage Center completed a report entitled Gas Bubble Trauma Monitoring and Data Reporting which can be found in Appendix M. Appendix N is the Corps' TDG TMDL Implementation Summary providing an overview of the status of the Corps' TDG activities.

1.1 Clean Water Act and Endangered Species Act

1.1.1 General

The Corps' water quality monitoring program at 12 Corps dams performs the following functions:

1. Monitor project performance in relation to water quality standards,
2. Provide water quality data for anadromous fish passage at Columbia/Snake mainstem dams.

The monitoring performed by the Corps' Reservoir Control Center is part of a larger interagency water quality monitoring system operated by the Corps that also includes the BoR monitoring system, and the Washington Public Utility District (PUD) monitoring systems (as conducted by Chelan County PUD, the PUD of Douglas County, and the Grant County PUD).

TDG and water temperature are primary water quality parameters monitored in the mainstem Columbia and Snake Rivers in the states of Idaho, Montana, Oregon and Washington. TDG may be influenced by project water management operations (e.g. water released over the dam spillways, releases through the powerhouses and other facilities, and forebay and tailwater water surface elevations) as well as environmental factors including water temperature and wind conditions.

1.1.2 Corps Goals

The Corps policy is to comply with water quality standards to the extent practicable regarding nationwide operation of water resources projects. The general policies of the Corps are summarized in the **Corps Digest of Water Resources Policies and Authorities**, Engineering Pamphlet 1165-2-1, dated 30 July 1999. Section 18-3.b, page 18-5 of this document states,

> "Although water quality legislation does not require permits for discharges from reservoirs, downstream water quality standards should be met whenever possible. When releases are found to be incompatible with state standards they should be studied to establish an appropriate course of action for upgrading release quality, for the opportunity to improve water quality in support of ecosystem restoration, or for otherwise meeting their potential to best serve downstream needs. Any physical or operational modification to a project (for purposes other than water quality) shall not degrade water quality in the reservoir or project discharges."

1.1.3 Biological Opinion (BiOp)

1.1.3.1 Background

Data from the Corps Dissolved Gas Monitoring Program prior to 1984 was used to monitor consistency with water quality standards. In 1984, the Corps Dissolved Gas Monitoring Program was enhanced to serve the dual purposes stated in Section 1.1.1.

With the listing of certain Snake River salmonids in 1991 under the Endangered Species Act (ESA), the Corps implemented a variety of operational and structural measures to improve the survival of listed stocks. The National Marine Fisheries Service (NMFS) 1992 BiOp called for providing summer spill of available water for flow augmentation for migrating juvenile salmon. Spill for fish at the lower Snake River projects was limited to Lower Monumental and Ice Harbor dams. In 1994, the program was further expanded in response to the NMFS request to release water over the spillways at the lower eight Columbia and Snake River mainstem dams up to a level of 120% TDG.
Water management operations to reduce water temperature in the lower Snake River for the benefit of adult Snake River fall Chinook salmon were also considered. The NMFS BiOp concluded that although the priority for cool water releases from Dworshak Dam were for migrating juvenile fall Chinook in July and August, releases to reduce water temperatures in September could be considered on an annual basis through the NMFS Regional Forum Process.

1.1.3.2 USFWS and NOAA Fisheries BiOps

USF&WS 2000 BiOp

According to the USF&WS 2000 BiOp operational and structural changes are to be made to reduce uncontrolled spill and the effects of high levels of TDG at lower Columbia River dams if it is determined that bull trout are affected by the FCRPS.

NOAA Fisheries 2000 and 2004 BiOps

The NOAA Fisheries 2000 BiOp and the 2004 BiOp identified metrics that were indicative of juvenile fish survival to meet system-wide performance objectives. It was recognized that, in many instances, actions taken for the conservation of ESA-listed species also move toward attainment of State TDG and water temperature standards. There were 14 actions in the Reasonable and Prudent Alternatives (RPA actions 130 to 143) identified as part of a water quality strategy in the NOAA Fisheries 2000 BiOp. Specifically, RPA actions 131 and 132 deal with water quality monitoring. RPA action 131 indicates that the physical and biological monitoring programs are to be developed in consultation with the NOAA Fisheries Regional Forum Water Quality Team and the Mid-Columbia PUDs. RPA action 132 specifies that a plan must be developed to perform a systematic review and evaluation of the TDG FMSs in the forebays of all the mainstem Columbia and Snake River dams.

The National Wildlife Federation and several other parties challenged the adequacy of the 2004 FCRPS BiOp. In October 2005, the U.S. District Court of Oregon found the 2004 FCRPS BiOp invalid and remanded to NOAA Fisheries. For the 2008 salmon migration season, the Corps operated in accordance with the court ordered 2008 Fish Operations Plan (FOP). The 2008 Fish Operations Plan can be found as Appendix C.

The NOAA Fisheries 2008 Biological Opinion was issued on 5 May 2008 and implementation of all hydrosystem operations identified in the 2008 BiOp would begin 1 September 2008.

1.1.4 TDG Standards

State of Idaho:
IDAPA 58.01.02-250: Surface water Quality Criteria for Aquatic Life Use Designations. 01(b): The total concentration of dissolved gas not exceeding one hundred and ten percent (110%) of saturation at atmospheric pressure at the point of sample collection.

State of Montana:
ARM 17.30.637(9): No pollutants may be discharged and no activities may be conducted which, either alone or in combination with other wastes or activities, result in the total dissolved gas pressure relative to the water surface exceeding 110% of saturation.

State of Oregon:
The Oregon **OAR 340-041-0031** regulation on Total Dissolved Gas TDG water quality standards state:

- Waters will be free from dissolved gases, such as carbon dioxide, hydrogen sulfide, or other gases, in sufficient quantities to cause objectionable odors or to be deleterious to fish or other aquatic life navigation, recreation, or other reasonable uses made of such water.
- Except when stream flow exceeds the ten-year, seven-day average flood, the concentration of total dissolved gas relative to atmospheric pressure at the point of sample collection may not exceed 110 percent of saturation. However, in hatchery-receiving waters and other waters of less than two feet in depth, the concentration of total dissolved gas relative to atmospheric pressure at the point of sample collection may not exceed 105 percent of saturation.

State of Washington:

In 2006, the State of Washington completed a revision of their water quality standards. The standards specify that TDG shall not exceed 110 percent of saturation at any point of sample collection for all designated Aquatic Life Uses. They also specified that this water quality criterion shall not apply when the stream flow exceeds the seven-day, ten-year frequency flood. An additional provision of the standard was that the TDG criteria may be adjusted to aid fish passage over hydroelectric dams when consistent with a department approved gas abatement plan.

One change from the previous standards (1997) is its rule on TDG to allow for adjusted TDG criteria when spilling water over dams to aid fish passage. This new rule (WAC 173-201A-060(4)(a)), states that, subject to approval of a gas abatement plan, and submission of a fisheries management plan, and plans for physical and biological monitoring, TDG levels in the river may be elevated to allow increased fish passage without causing more harm to fish populations than caused by turbine fish passage. The exemption requires that, when spilling water at dams is necessary to aid fish passage, TDG must not exceed an average of one hundred fifteen percent (115%) as measured in the forebays of the next downstream dams. TDG must also not exceed an average of one hundred twenty percent (120%), as measured in the tailraces of each dam. These averages are based on the twelve highest consecutive hourly readings in any one day of total dissolved gas. In addition, there is a maximum TDG one hour average of one hundred twenty-five percent (125%), relative to atmospheric pressure, during spillage for fish passage.

1.1.5 TDG Waiver History

State of Oregon

The first Federal request for a TDG waiver was submitted to the Oregon Department of Environmental Quality (ODEQ) in 1994. The Corps obtained a waiver for the 2002 migration season (April 1, 2002 to midnight August 31, 2002). The Commission approved a modification to the TDG standard for spill on the Columbia River of a daily (12 highest hours) average of 115% as measured at the forebay monitoring stations of McNary, John Day, The Dalles, and Bonneville dams, and at the Camas/Washougal monitoring station. They approved a cap on TDG for the Columbia River during the spill program of 120% measured at the McNary, John Day, The Dalles, and Bonneville dams' tailwater monitoring stations, based on the average of the 12 highest hourly measurements per calendar day. The Commission also approved a cap on TDG for the Columbia River during the spill program of 125%, based on the highest two hours per calendar day. The Commission also required that if 15% of the juvenile fish examined showed signs of GBT in their non-paired fins, where more than 25% of the surface area of the fin was occluded by gas bubbles, the waiver would be terminated.

The following conditions were incorporated into the Commission's waiver. The Corps was to provide written notice within 24 hours to the ODEQ on any exceedances of the conditions in the waiver as it relates to voluntary spill. The Corps was to provide a written report of the 2002 spill program by December 31, 2002 and supply information on the levels of TDG, fish monitoring, and incidence and severity of GBT. Additionally, any proposal for a modification to the TDG standard in 2003 was to be received by the ODEQ no later than December 31, 2002.

On December 23rd, 2002, the Corps submitted information for a multi-year TDG waiver to the ODEQ. The Oregon Environmental Quality Commission met on March 11th, 2003 and approved a 5-year TDG waiver subject to the same restrictions and conditions as the previous waiver. This new waiver was in effect from April 1 through August 31 of each year through the 2007 spill season.

On November 30, 2006, the Corps submitted a package of information to ODEQ for its use in processing a multi-year waiver to the Oregon TDG standard for the period 2008 through 2012 with the same conditions as specified in the previous waiver. The Oregon Environmental Quality Commission met on June 21, 2007 and approved a 2-year waiver for the 2008-2009 spill seasons. The waiver issued was similar to the previous waivers with the exception that the 115% criterion, as measured at the Camas-Washougal fixed monitoring station, was removed and that the year-end report include a description and results of any biological or physical studies of spillway structures and prototype fish passage devices to test spill at operational levels. It also included a provision for Adaptive Management, which outlined a process for the evaluation of appropriate points of compliance for the 2002 Lower Columbia River TDG TMDL.

State of Washington:

In its 1997 water quality standards, the State of Washington modified its rule on TDG to allow for adjusted TDG criteria when spilling water over dams to aid fish passage. This new rule (WAC 173-201A-060(4)(a)), stated that, subject to approval of a gas abatement plan, and submission of a fisheries management plan, and plans for physical and biological monitoring, TDG levels in the river may be elevated to allow increased fish passage without causing more harm to fish populations than caused by turbine fish passage. The exemption required that, when spilling water at dams is necessary to aid fish passage, TDG must not exceed an average of 115% as measured at the Camas/Washougal FMS site below Bonneville dam or as measured in the forebays of the next downstream dams. TDG must also not exceed an average of 120%, as measured in the tailraces of each dam. These averages are based on the twelve highest hourly readings in any one day of TDG. In addition, there is a maximum TDG one hour average of 125%, relative to atmospheric pressure, during spillage for fish passage.

In December 2002, the Corps submitted a package to the Washington Department of Ecology (WDOE) concerning the TDG criteria adjustment. In a letter to the Corps of Engineers dated March 28, 2003, the WDOE approved the gas abatement plan for all activities related to fish passage for a period of one year.

In December 2003, the Corps submitted another package to the WDOE containing a Water Quality Plan, which was greatly expanded and covered a period extending through 2015. In response to this submittal, the WDOE approved another one-year TDG rule adjustment beginning February 27, 2004.

On January 14, 2005, the Corps submitted another package of documents concerning the State of Washington's TDG rule adjustment. In this package, the gas abatement plan was updated as of December 2004. Based on this submittal and additional coordination with the Corps and ODEQ, the WDOE approved the rule adjustment for a period of three years (through February 2008).

In addition to the TDG information described above, the Corps was to continue to investigate and pursue TDG reduction and monitoring improvements as new information becomes available, continue to investigate biological effects of TDG, make reasonable attempts to reduce gas entrainment during all flows during the spill season, plan maintenance schedules and activities as much as possible to minimize TDG production, notify WDOE within 48 hours of initiation of spring, summer, and other spills for fish, and provide the WDOE with an annual written report detailing TDG issues and characteristics for each year of spill season.

On November 30, 2006, the Corps submitted another package of documents concerning the State of Washington's TDG criteria adjustment. In this package, the gas abatement plan was updated as of December 2006. Based on this submittal and additional coordination with the Corps and ODEQ, the WDOE approved the Corps' Water Quality Plan for a period of two years (through February 2010). In addition to the reporting requirements that were requested in previous rule adjustments, the Corps was to investigate and pursue TDG reduction improvements for all projects on the lower Columbia and Snake rivers and Chief Joseph Dam, and to produce a draft report by October 31, 2008 with a final report by December 31, 2008. This investigation will evaluate each dam's ability to meet water quality standards for TDG.

Colville Tribe TDG Standards:

4-8-5(e): The Water Quality Standards herein established for the total dissolved gas shall not apply when the stream flow exceeds the seven (7) day, ten (10) year frequency flood.

4-8-6 (b) (3) (E): Total Dissolved gas shall not exceed one hundred-ten (110%) percent of saturation at any point of sample collection.

1.1.6 TDG TMDL Progress

The states requested technical information on the progress of implementing actions contained in the Lower Columbia and Snake Rivers TDG TMDL. Appendix N contains several summary tables that provide an overview of the status of the Corps' TDG TMDL implementation activities, both short-term and long-term. These activities were recommended in the "Total Maximum Daily Load (TMDL) for Lower Columbia River Total Dissolved Gas (Sept 2002)," and the "Total Maximum Daily Load (TMDL) for Lower Snake River Total Dissolved Gas (Aug 2003)."

Table N-1 in Appendix N provides the current status of the short-term TDG TMDL implementation actions. There are some actions in this table that were not included in the TDG TMDL original list, but are being implemented in the hydrosystem, so they were included. Table N-2 in Appendix N provides the operational implementation actions that can be taken to minimize TDG. Table N-3 in Appendix N provides the current status of the long-term TDG TMDL Implementation activities.

1.1.7 Operating Guidelines

The Water Quality Unit of the Corps' Northwestern Division Columbia Basin Reservoir Control Center is responsible for monitoring the TDG and water temperature conditions in the forebays and the tailwaters of the lower Columbia River and lower Snake River dams, and selected river sites. The Columbia Basin District water quality staff operates and maintains the gages. In accordance with the Corps' Northwestern Division operational water management guidelines that dictate changing spill levels and potentially, spill patterns, the dams are monitored and operations are changed (daily, if necessary) so that TDG levels are consistent with the applicable state standards (including waivers or criteria adjustments). Currently, forebay TDG levels are not to exceed a daily (12 highest hours) average of 115%, and the tailwater levels do not exceed a daily (12 highest hours) average of 120% TDG. When these adjustments are made, the water volume, water elevation (where applicable), project powerhouse and spillway characteristics (where applicable), current and near-future special operations, current TDG levels in the forebays and tailwaters, water temperatures, and short- and long-term weather forecasts are included in the evaluation.

Part 2 Program Operating Conditions

2.1. Water Year Runoff Conditions

2.1.1 Weather

The 2008 Water Year (WY), which began in October 2007, was average in precipitation. The accumulative precipitation during WY 2008 in the upper Columbia River Basin was 95 percent of normal (1971-2000) above Grand Coulee Dam, 96 percent of normal in the Snake River above Ice Harbor Dam, and 96 percent of normal in the Columbia River above The Dalles, Oregon as determined by the Western Region Climate Center. The following month-by-month discussion of the weather provides more detailed information.

In October 2007, cool and wet weather systems moved through the Columbia Basin with a couple of exceptionally wet storms. U.S. sector temperatures departed about -0.3ºC (-0.6ºF) from normal, and had a mix of record high and low temperatures. October precipitation was 141 percent of normal at the Columbia River above Grand Coulee, 175 percent of normal at the Snake River above Ice Harbor, and 143 percent of normal at the Columbia River above The Dalles. At the close of the month high pressure returned to the region, for drying and warming leading into November.

In November 2007 a high pressure system brought some record high temperatures to the region early in the month with warmer than average weather continuing into mid-month, even with increased precipitation. Then, toward the close of November, a strong cold front introduced much colder temperatures, cold enough for valley snow accumulation east of the Cascade Range. November precipitation was 84 percent of normal at the Columbia River above Grand Coulee, 85 percent of normal at the Snake River above Ice Harbor, and 83 percent of normal at the Columbia River above The Dalles.

In December, the La Niña of 2007 opened with strong storms bringing heavy, and in many cases, record rain to many areas. December started warmer than normal, with many record high temperatures. Much colder air arrived about mid-month, and helped set, or tie, record low temperatures at Boundary Dam, Washington, at -17.2ºC (1ºF), and Meacham, Oregon, at -15ºC (5ºF), a tied record, set on Christmas Day. Given that the region saw roughly a 5.6ºC (10ºF) temperature swing during the month, December ended up warmer than normal, departing +0.6ºC (+1ºF). On the precipitation side, 130 percent of normal was tallied at the Columbia River above Grand Coulee, 119 percent of normal at the Snake River above Ice Harbor, and 115 percent of normal at the Columbia River above The Dalles.

January 2008 brought a warm start to 2008, as milder air replaced the late December cold, but it did not last long as a colder air mass returned, via a north-to-northwest airflow. Early month warmth, with a record high at Walla Walla, Washington, on the 4th at 15.6ºC (60ºF), was blown out mid- to late-month by exceptionally cold air resulting in the following daily records: -36.7ºC (-34ºF) at Potomac, Montana; -36.1ºC (-33ºF) at Libby, Montana; -28.3ºC (-19ºF) at Meacham, Oregon; -21.7ºC (-7ºF) at Shoup, Idaho; -34.4ºC (-30ºF) at Stanley, Idaho; -3.9ºC (25ºF) at Seattle Washington; -22.2ºC (-8ºF) at Boundary Dam, Washington; and -15.6ºC (4ºF) at Wenatchee, Washington. The month ended up cold, at -1.2ºC (-2.1ºF) from normal. January precipitation was 103 percent of normal at the Columbia River above Grand Coulee, 115 percent of normal at the Snake River above Ice Harbor, and 106 percent of normal at the Columbia River above The Dalles.

Starting out chilly, February 2008 warmed to produce some record high temperatures: Quillayute, Washington, 15.6ºC (60ºF), Seattle, Washington, 13.9ºC (57ºF) and 16.1ºC (61ºF). There were no record low temperatures set. Relative to normal, February departed by +0.7ºC (+1.2ºF). A ridge of high pressure, that frequently moved far offshore to allow the chilly weather systems from mid-December through January to enter, moved in overhead for much of the month. February precipitation was 92 percent of normal at the Columbia River above Grand Coulee, 94 percent of normal at the Snake River above Ice Harbor, and 89 percent of normal at the Columbia River above The Dalles.

By March, the La Niña event had peaked but continued to signal higher than normal pressure just off the Pacific Northwest coast. The high kept most areas of the basin drier than normal, except where the northwest flow of the past couple of months edged toward the northern Rockies. Here, persistent precipitation kept snowfall in the headwater drainages nearest the Continental Divide. It was a cool month, indicated by a departure of -1.2ºC (-2.2ºF). March had some record low temperatures: Chief Joseph Dam, Washington, -3.9ºC (25ºF); Yakima, Washington, -6.7ºC (20ºF); Madras, Oregon, -7.8ºC (18ºF); and Redmond, Oregon -12.2ºC (10ºF). It was generally a drier than normal month, with the Columbia River above Grand Coulee registering 79 percent of normal precipitation, the Snake River above Ice Harbor at 92 percent of normal, and 88 percent of normal at the Columbia River above The Dalles.

In April, an early period warm spell led to record high temperatures at Boise, Idaho, and Burns, Oregon, each with 26.7ºC (80ºF), and tying record high temperatures for Missoula and Kalispell, Montana, at 26.1ºC and 23.3ºC (79ºF and 74ºF), respectively. Again caused by the position of high pressure, a strengthening offshore brought very cold air into the basin. As such, and given the time of year when very chilly air stands out against an increasing sun angle and warmth, many record low temperatures were observed. Much cooler than normal weather delayed the snow melt. Precipitation in April averaged 102 percent of normal at the Columbia River above Grand Coulee, 106 percent of normal at the Snake River above Ice Harbor, and 103 percent of normal at the Columbia River above The Dalles.

In May, warmer temperatures were observed and the region departed +0.4ºC (+0.8ºF) with a run of abruptly warmer than normal weather about mid-month. This depleted the lower elevation snowpack, as well as bringing snowmelt rises to flood stage on many Columbia Basin tributaries. Some record rainfall fell over southern Oregon this month: Medford, daily record of 1.14 cm (0.45”) and Klamath Falls, 1.32 cm (0.52”). For the month, precipitation was 99 percent of normal at the Columbia River above Grand Coulee, 102 percent of normal at the Snake River above Ice Harbor, and 100 percent of normal at the Columbia River above The Dalles.

In June regional temperatures departed -1.6ºC (-2.8ºF), coldest relative to normal in B.C., northeast Washington and in the Willamette Basin. There remained mid- through high-elevation snow, although mid-elevation amounts edged downward. Precipitation was below normal in the most southern Columbia/Snake River basins, but above normal in western Washington, coastal Oregon, in northern Idaho, northwest Montana, and in B.C. The benefits in Canada offset the U.S. deficits: precipitation was 98 percent of normal at the Columbia River above Grand Coulee, 99 percent of normal at the Snake above Ice Harbor, and 99 percent of normal at the Columbia River above The Dalles.

In July summer temperatures experienced regional departures to +0.7ºC (+1.2ºF) from normal. This caused peak runoff conditions especially early to mid-month. The warmest temperatures, relative to normal were east of the Cascades. A mid-month "heat wave" west of the Cascades just gave Portland a quick run at 32.2ºC (90ºF) heat. The high pressure that was once offshore moved inland during the month, and attempted to pull monsoonal moisture northward into the Basin. Combined with cool fronts across Canada, the regional precipitation was 95 percent of normal at the Columbia River above Grand Coulee, 96 percent of normal at the Snake River above Ice Harbor, and 96 percent of normal at the Columbia River above The Dalles.

A moisture surge from the south occurred in August, as did the hottest temperatures of the summer. High pressure from July was solidly and strongly inland for August, bringing record heat, as well as warm overnight temperatures. The region recorded a +0.8ºC (+1.5ºF) departure for the month. August is the warmest month of the year for much of basin. Precipitation was 99 percent of normal at the Columbia River above Grand Coulee, 95 percent of normal at the Snake River above Ice Harbor, and 97 percent of normal at the Columbia River above The Dalles.

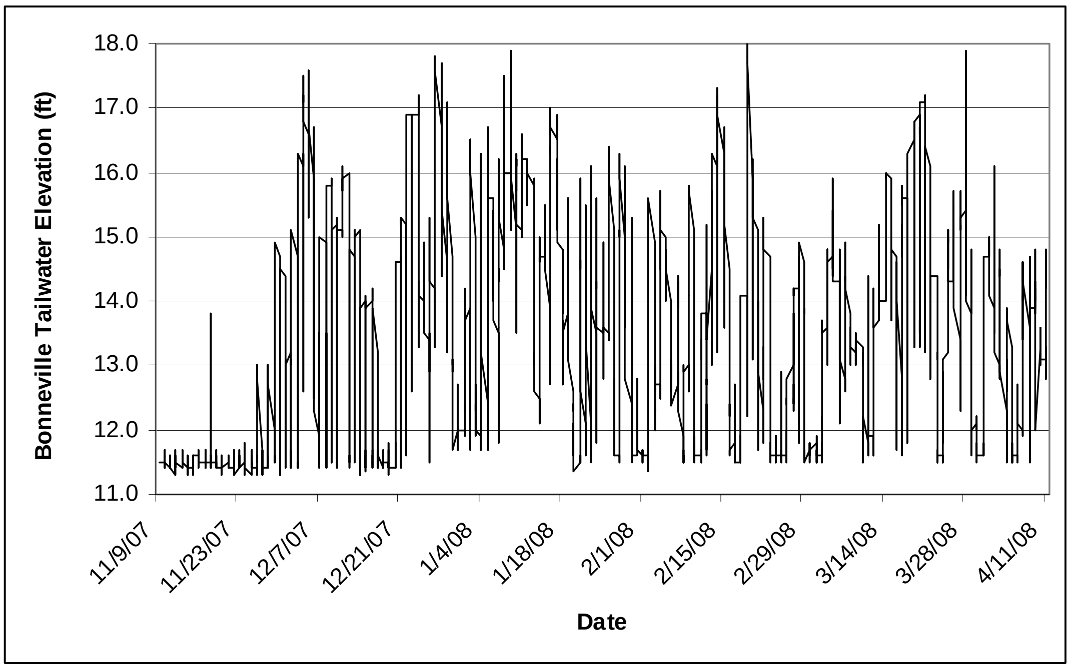
Upper-level high pressure sat offshore of, yet close enough to, the basin, to bring generally drier than normal weather to the region for September. As such, precipitation was below normal, except in the far northern Upper Columbia basin, where amounts were near normal. Storms broke through the top of the high mid to late in the month, and brought some isolated daily record rainfall amounts amidst the drier conditions. They included: Kalispell, Montana, with 2.2 cm (0.87"); Seattle, Washington, with 1.3cm (0.53"); Boise, Idaho, with 2.3 cm (0.90"); and Mullan Pass, Idaho, with 1.6 cm (0.63"). Overall, precipitation was 97 percent of normal at the Columbia River above Grand Coulee, 92 percent of normal at the Snake River above Ice Harbor, and 95 percent of normal at the Columbia River above The Dalles.

2.1.2 Streamflow

The 1 April 2008 forecast of January through July runoff for the Columbia River above The Dalles was 124.6 km^3 (101.0 Maf) and the actual observed runoff was 122 km^3 (99.2 Maf). The average January-July runoff volume for the 1971-2000 period is 132.4 km^3 (107.3 Maf).

In accordance with the 2004 NMFS BiOp, the Columbia River was operated to provide conditions conducive for chum salmon spawning and egg incubation below Bonneville Dam from November 9, 2007 through April 11, 2008. Instantaneous Bonneville Dam tailwater elevation, as measured at the Tanner Creek gage, was specified as a minimum of 11.3 feet during all hours and 11.3 to 11.7 feet during daytime hours (0600-1800 hours). Due to high river discharge throughout the 2007-08 operational period, it was not possible to maintain the specified tailwater elevation range at all times. As a consequence, hourly tailwater elevation ranged from 11.3 to 18.1 feet and averaged 13.4 feet throughout the operational period (Figure 1). Hourly discharge at Bonneville Dam during the operational period ranged from 81 to 228 kcfs and averaged 141 kcfs throughout the operational period.

Figure 1
Instantaneous Bonneville Dam tailwater elevation at the Tanner Creek gage November 9, 2007 to April 11, 2008.



Composite operating year unregulated streamflows in the Basin above The Dalles were below normal and approximately 0.5 percent above last year's below average streamflows. Table 1 provides the unregulated flows for each month at Grand Coulee and The Dalles. Month average unregulated inflows during spring runoff were highest in May 2008, 117 percent of average, at The Dalles.

The August 2007 through July 2008 runoff for The Dalles was 151.6 km^3 (122.9 Maf), 89 percent of the 1971-2000 average. The peak-unregulated discharge for the Columbia River at The Dalles was 19,576 m^3/s (691.3 kcfs) on 3 June 2008. The 2007-2008 average monthly unregulated streamflows and their percentage of the 1971-2000 average monthly flows for the Columbia River at Grand Coulee and The Dalles are shown in Table 1 for the Columbia River at Grand Coulee and The Dalles. These flows have been adjusted to exclude the effects of regulation provided by storage reservoirs.

TABLE 1

Columbia River Flows in 2007-2008				
	At Grand Coulee (in cfs)		At The Dalles (in cfs)	
Time Period	Unregulated flow	% of Average	Unregulated flow	% of Average
October 2007	43,800	98	76,500	92
November 2007	38,100	78	74,900	79
December 2007	38,100	88	78,700	80
January 2008	30,400	73	65,700	64
February 2008	30,300	64	73,400	60
March 2008	38,500	62	96,300	62
April 2008	57,000	47	119,800	50
May 2008	310,600	117	508,700	117
June 2008	331,500	107	518,900	110
July 2008	186,900	97	257,900	100
August 2008	98,000	93	130,900	95
September 2008	52,600	84	79,400	85
Operating Year Average (Oct 07 – Sep 08)	104,650	84	173,425	83

2.1.3 Reservoir Operation

2.1.3.1 General

The 2007 – 2008 operating year began with Grand Coulee storage at 90.8% full. It was one of average water supply across the basin, and the shape of the runoff included one significant peak starting the later half of May and continuing through June and ending the first week of July. The 2007-2008 operating year began with Canadian storage at 99.2% full. Libby reservoir (Lake Koocanusa) was approximately seven feet from full (storage about 93.6% full), elevation 748.85 m (2,452.1 ft), at the start of the operating year. Per the 2004 NOAA Fisheries BiOp, water was being released from Libby to provide for flow augmentation for listed salmon and steelhead.

The 2007–08 operating year was one where water supply in the Columbia River above Grand Coulee and the Snake River at Lower Granite were slightly below average.

However, water supply was slightly below normal. The streamflow in March and April was well below average in the basin. The remainder of the snowmelt season through July was characterized by above average runoff above Grand Coulee.

The Libby project was operated according to the Libby Coordination Agreement (LCA) dated February 2000, including the 21 April 2006 update to the Libby Operating Plan, and U.S. requirements for power and guidelines set forth in the 2006 USFWS and 2004 NMFS BiOps. On July 2007, the Libby reservoir was at elevation 746.7 m (2,450 ft), and was drafted through the fall and winter period. By 31 December, the reservoir was at elevation 734.9 m (2,411 ft) and operated during the winter according to the VARQ storage reservation diagram. The reservoir was drafted to its lowest elevation of 730.03 m (2,395 ft) on 13 April 2008. During the refill period, Libby Dam was operated in accordance to the VARQ operating procedures and provided 1.28 km^3 (1.04 Maf) of storage for sturgeon releases. The reservoir was filled to its maximum elevation of 745.2 m (2445 ft) on 18 July 2008 and continued to draft to elevation 744.2 m (2442 ft) by 31 August 2008.

2007-2008 operations were consistent with the 2004 NMFS BiOps, and the 2000 USFWS FCRPS BiOp and the 2006 USFWS Libby BiOp. The operations included refilling reservoirs to the 10 April flood control elevation and if inflow was sufficient: 1) refill on, or about 30 June, and; 2) drafting reservoirs to summer draft limits. The spring flow objectives were met at Priest Rapids, McNary and Lower Granite. Spring and summerspill for fish passage was executed at the lower Columbia and Snake River projects. The lower Snake River projects were operated within one foot of their minimum operating pools (MOP) for the migration season.

2.1.3.2 Flood Control

The 2008 water supply forecasts were slightly below normal across the Columbia Basin and the upper Columbia Basin. The Snake River Basin was slightly above normal. The reservoir system, including the Columbia River Treaty projects, was required to draft for flood control in preparation for the spring freshet. Projects were operated according to the May 2003 Flood Control Operating Plan (FCOP). The Columbia River unregulated peak flow at The Dalles was estimated at 19,576 m^3/s (691.3 kcfs) on 3 June 2008. A regulated peak flow of 11,451 m^3/s (404.4 kcfs) occurred on 5 June 2008, as measured at the United States Geological Survey (USGS) gaging station at The Dalles. The unregulated Columbia River peak stage at Vancouver, Washington was calculated to be 7.28 m (23.9 ft) on 4 June 2008; the highest observed stage was 4.51 meters (m) (14.8 ft) on 22 May 2008.

During the 2008 migration season, flows were such that spill for flood control was required on the lower Columbia and Snake from 17 May through 4 July. Daily average flow on the lower Columbia River stayed above 400 kcfs from 28 May through 6 June. On the lower Snake River, total river daily average flow was 185 to 199 kcfs between 19 May and 22 May. Daily average flows on the Lower Snake remained between 128 and 166 kcfs through 8 June.

As established through coordination with Oregon and Washington, when flows exceed the 7Q10 (the average peak annual flow for seven consecutive days that has a recurrence interval of ten years), due to limited powerhouse capacities, spill levels required to pass the high flows result in TDG levels that exceed State TDG criteria. Calculated 7Q10 flows at each project on the lower Columbia and Snake rivers are shown in Table 2.

TABLE 2
7Q10 FLOWS

Project	7Q10 flows (kcfs)	Powerhouse capacity within 1% efficiency (kcfs)	Powerhouse capacity without one unit (kcfs)	Rate of spill at 7Q10 flows† (kcfs)
Bonneville	467	257	242	225
The Dalles	461	288	267	194
John Day	454	331	310	144
McNary	447	172	160	287
Ice Harbor	214	92	77	137
Lower Monumental	214	115	94	120
Little Goose	214	115	94	120
Lower Granite	214	115	94	120

† Assuming no generation limitation due to "lack of load."

The 2008 peak flows on the lower Columbia and Snake rivers did not exceed the 7Q10 flow. The Columbia River at Bonneville reached an average daily flow of 519 kcfs from 1 June through 21 June in 1997. Flows at the Columbia River at Bonneville also exceeded the 7Q10 flow in1974. The 7Q10 flow was frequently reached at multiple projects during 1960's and 1970's.

The spill data in Appendix D provides an accounting of voluntary spill and involuntary spill at each of the 8 projects on the lower Columbia and Snake rivers. During the peak runoff period, there was involuntary spill at all eight projects with involuntary spill lasting from 17 May through 4 July, which is longer than in recent water years.

2.1.3.3 Chief Joseph and Grand Coulee Spill Shift

In 2002, the Action Agencies, NOAA Fisheries, Washington Department of Ecology and the Colville Tribe discussed the potential benefit to upper Columbia River water quality through joint operations of Grand Coulee and Chief Joseph dams in the absence of spillway deflectors at the latter project. This proposal is referred to as the "Chief Joseph-Grand Coulee Spill Shift. In coordination with the Regional Forum Water Quality Team (WQT), the Corps conducted a study that concluded that reductions to TDG levels could be achieved in the Mid-Columbia River through joint operations of Grand Coulee Dam and Chief Joseph Dam (*"Joint operation of Chief Joseph and Grand Coulee Dams for Power* *and Total Dissolved Gas,"* M. Schneider 2003). The study investigated the consequences of TDG saturation in the Mid-Columbia River from spilling via the outlet works at Grand Coulee Dam versus spilling via the existing spillway, with no flow deflectors, at Chief Joseph Dam. Joint operations of Grand Coulee and Chief Joseph was recommended to reduce the average cross-sectional TDG saturations in the Columbia River above and below Chief Joseph by taking advantage of the larger generation flow capacity of Grand Coulee and the lower average TDG loading below the Chief Joseph spillways (absent deflectors). Study results predicted that joint operations would decrease the average TDG saturation in the Columbia River below Chief Joseph and Grand Coulee dams, but increase the localized TDG saturation in an area below the Chief Joseph spillway.

Flow deflector construction was completed at Chief Joseph Dam in October 2008. Due to the on-going construction activities during the run-off season of 2008, joint operations with Grand Coulee were not possible during construction due to the limited number of spillway bays available at Chief Joseph Dam. Due to completion of the spill deflectors, joint operations with Grand Coulee will again be a viable alternative to reduce TDG saturations in the Columbia River. However, a post-deflector spill test will need to be conducted at Chief Joseph Dam to determine the TDG exchange properties during spillway discharges with flow deflectors prior to implementing any joint operations. A spill test at Chief Joseph Dam is tentatively scheduled to be conducted in the spring of 2009.

Part 3 Fixed Monitoring Stations

3.1 FMS Stations

TDG and temperature are monitored throughout the Columbia River Basin via fixed monitoring stations (FMSs). There are a total of 42 FMSs in the U. S. portion of the Columbia River basin. The Corps operates 28 FMSs. The BoR, and the Chelan and Grant County PUDs each operate four stations. Two stations are operated by the Douglas County PUD. The Portland, Seattle, and Walla Walla Corps Districts operate and maintain the FMSs in the Columbia and Snake River basins. Portland District is responsible for 8 FMSs on the lower Columbia River from John Day Dam to Camas-Washougal. The Seattle District is responsible for 5 FMSs in the Upper Columbia Basin (at Chief Joseph, Albeni Falls, and Libby dams). Walla Walla District is responsible for 15 FMSs in the Snake River and Clearwater River basins, and at McNary Dam on the Columbia River. Appendix A contains information about each FMS operated by the Corps and a map of their locations.

3.2 Monitoring Plan of Action

The Corps prepares a Dissolved Gas Monitoring Plan of Action each year. The Plan summarizes the roles and responsibilities of the Corps as they relate to dissolved gas monitoring. The Plan stipulates what to measure, how, where, and when to take the measurements and how to analyze and interpret the resulting data. The Plan also provides for periodic review and alteration or redirection of efforts when monitoring results and/or new information from other sources justifies a change. The 2008 Plan (Appendix B) identifies channels of communications with other cooperating agencies and interested parties.

This plan is a supporting document for the NOAA Fisheries Regional Forum Technical Management Team to make recommendations on dam and reservoir operations. The TMT web site can be found at: http://www.nwd-wc.usace.army.mil/tmt/

The 2008 Plan of Action can also be found at the following web site: http://www.nwd-wc.usace.army.mil/TMT/wqwebpage/mainpage.htm

3.3 Changes in the Fixed Monitoring System

The only noteworthy change to the Corps TDG FMS system during 2008 was the installation of high data rate collection platforms (DCPs) that can transmit data hourly instead of every four hours. The DCP installation was phased in over a two year span from 2007 through 2008.

3.4 Malfunctioning Gage Occurrences

During 2008 there were five occurrences where a FMS station gage malfunctioned due to a punctured membrane. As a result, the data from these FMS gages showed elevated TDG levels ranging from approximately 137% to 154%. Refer to Table F-7 in Appendix F for information regarding malfunctioning gages. Table F-7 details the Exceedance Types #10, which is an exceedance due to a malfunctioning gage. Table F-2 indicates that there were 10 days where the high 12-hour average exceeded 120% due to exceedance type #10. Table F-2 is based on raw data and is filled out during real-time operations.

The Albeni Falls' forebay and tailwater FMSs were destroyed by high flows. These gauges could not be fixed until flows were much lower, which didn't occur until after the spill season.

Since the data from malfunctioning gages is seriously questionable due to the malfunctioning gages, the Corps removed it from their database. This data is not reflected in Tables F-4, F-5 or F-6.

3.5 QA/QC on FMS stations

Data Quality Criteria (DQC) for FMSs in the Pacific Northwest were developed in order to meet some of the requirements of RPA (Reasonable and Prudent Alternative) 131 and 198 of the 2000 BiOp. The NMFS 2000 BiOp RPA Action 131 specified that the "Action Agencies shall monitor the effects of TDG." Further discussion in the RPA was a description of QA/QC guidelines, which including redundant and backup monitoring, bi-weekly calibration, and spot-checking of monitoring equipment. In an effort to address these concerns the Corps developed DQCs for the FMSs at its projects. The DQCs describe the accuracy, precision and completeness of the data needed at each station. The FMSs would be assessed at the end of the monitoring season against these criteria and a performance report would be provided to the region. The performance reports can be found as Appendix J, Appendix K and Appendix L.

Adjustments would be made to the individual FMSs that do not perform to the objectives described. The DQC approach was recommended instead of the redundant and backup monitoring, and spot-checking approach described in the 2000 BiOp. This approach was used as a way of providing greater flexibility with equipment and has less impact on program cost escalation.

The NMFS 2000 Biological Opinion RPA 198 stated, "The Action Agencies, in coordination with NMFS, USFWS, and other Federal agencies, Northwest Power Planning Council (NWPPC), state, and Tribes, shall develop a common data management system for fish population, water quality, and habitat data."

In coordination with the USGS and the Regional Forum WQT, the Corps completed the initial DQC in April 2003. Since that time, through discussions with the USGS and the Regional WQT, the Corps has updated and revised these data quality criteria. For example, the calibration cycle has been changed from once every two weeks to once every three weeks during spill season and once every four weeks in fall/winter for the Portland and Walla Walla District gages. Gages operated by Seattle District staff are maintained once every two weeks during the fish season. The current DQC are outlined in the *Corps of Engineers Plan of Action for Dissolved Gas Monitoring in 2008*, which is provided in Appendix B.

3.5.1 Portland District QA/QC

Portland District is responsible for maintaining and operating the forebay and tailwater gages at John Day, The Dalles and Bonneville dams. This work is performed through a contract with the Portland office of the USGS. The highlights of the Portland District QA/QC report are:

- For the eight monitoring sites in water year 2008, an average of 99.6% of the TDG data was received in real-time by the USGS satellite downlink. Data received from the individual sites ranged from 98.8% to 100.0% complete. See Table 2 in Appendix K for individual gage data completeness information. These results exceed the data quality criteria for data completeness. Table 3 in Appendix K provides the causes for missing data.
- The TDG sensors were calibrated in the laboratory after field deployment for three or four weeks. All of the sensor readings were within 0.6% saturation. Of the 93 laboratory checks that were performed, only four indicated that a sensor needed recalibrating. The largest difference between expected versus actual TDG pressure was 4 mm Hg. These results meet or exceed the DQC for lab calibrations.
- Each of the in-situ field checks of TDG sensors with a secondary standard was within ±1% saturation after three to four weeks of deployment in the river.
- The eight FMSs were calibrated every three weeks, except from October 2007 through March 2008, when they were calibrated at four week intervals.

- All of the field checks of barometric pressure were within ±2.0 mmHg of a secondary barometric standard. The water-temperature field checks were all within ±0.2°C. These results exceed the DQC for the two-point TDG sensor calibrations.
- The eight monitoring sites in water year 2008 were within 1% saturation of the expected value on the basis of calibration data, replicate quality control measurements in the river, and comparison to ambient river conditions at adjacent sites.

The full detailed QA/QC report on the Portland District gages can be found in Appendix K.

3.5.2 Walla Walla District QA/QC

The Walla Walla District is responsible for maintaining and operating the forebay and tailwater gages at Lower Granite, Little Goose, Lower Monumental, Ice Harbor and McNary. This work is performed through a contract with the Pasco office of the USGS.

The highlights of the Walla Walla District QA/QC report are:

- For the fifteen monitoring sites maintained during the 2008 water year, an average of 99.7% of the TDG data were received in real time by the CROHMS satellite downlink. Data received from the individual sites ranged from 98.4% to 100.0% complete. See Table J-7 in Appendix J for individual station data completeness information. These results exceed the DQC for data completeness. Table J-8 in Appendix J provides the causes for missing data.
- The TDG sensors were calibrated in the laboratory after field deployment for three or four weeks. The average difference between the data sonde and the primary standard was 0%, as calculated from a sample size of 183 checks. Individual data sondes showed a range of -0.2% to 0.2%. The largest difference between expected versus actual TDG pressure was 2 mm Hg. These results meet or exceed the DQC for laboratory calibrations.
- The in-situ field checks of the total dissolved gas sensors with a secondary standard averaged 0%, with a range of -0.7% to 0.3% after three to four weeks of deployment in the river.
- All 15 FMSs are calibrated at three week intervals during the fish-spill season. The six year-round stations were calibrated at four week intervals between September 2007 and March 2008.
- The field checks of barometric pressure with a secondary standard were within an average of 0.01 mm Hg and ranged from -1.10 mm Hg to 1.00 mm Hg. The water-temperature field checks averaged -0.03°C and ranged from -0.40°C to 0.35°C. These results meet the DQC for the mean of differences between secondary standards and the field instruments.

- The 15 FMSs used in water year 2008 were within 1% saturation of the expected value on the basis of calibration data, replicate quality-control measurements in the river, and comparison to ambient river conditions at adjacent sites.

The full QA/QC report on the Walla Walla District gages can be found in Appendix J of this report.

3.5.3 Seattle District QA/QC

Seattle District is responsible for maintaining and operating the forebay and tailwater gages at Chief Joseph, Albeni Falls, and Libby dams. There is only a tailwater gage at Libby. This work is performed through a contract with the Columbia Basin Environment.

The highlights of the Seattle District QA/QC report are:

- For the five monitoring sites in water year 2008, an average of 83.5% of the TDG data were received in real-time from the DCP by a radio transmitter. Data received from the individual sites ranged from 76.9% to 86.5% complete. See Table 2 in Appendix L for individual gage data completeness information. These results do not meet the DQC for data completeness.

- Missing data for all stations in 2008 were largely due to DCP malfunctions and programming problems resulting from installing new Sutron 9210 XLite DCPs at all stations for the 2008 sampling season. In general, these problems occurred during the first 3 weeks of April and were resolved by May. In addition, high flows damaged the Albeni Falls tailwater station (ALQI) on July 17, 2008 at 0800 hours. The station was offline until a data logger DCP could be installed on July 21, 2008 at 0900 hours. Data obtained after the installation of the logger was not transmitted in real-time.

- Laboratory calibration data were good and within 0.1°C for temperature and 1% for TDG. Field calibration data were good and generally within 2mm Hg of the secondary standard barometer, 0.2ºC of the secondary standard thermometer, and 10 mm Hg saturation of the secondary standard TDG instrument. However, there were several barometric pressure differences that exceeded 2 mm Hg due to a resistor problem with the new DCPs. In addition, there were several total dissolved gas saturation differences that exceeded 10 mm Hg saturation. Outlier point TDG saturation differences ranging from 15 mm Hg at Chief Joseph forebay (CHJ) to 37 mm Hg at Libby tailwater (LBQM) were due to the secondary standard probe not being left in the water long enough at these stations to equilibrate. These results do not meet the data quality criteria for TDG.

- TDG saturations at Chief Joseph forebay station (CHJ) exceeded 110 percent from about the end of May to the end of August 2008. Forebay TDG concentrations exceeded 120% in early June with a maximum concentration of about 129% measured on June 5, 2008. The Chief Joseph tailwater station (CHQW) exceeded 110% TDG saturation from about the end of May to the end of August, 2008. However, the tailwater station did not exceed 120% during 2008. Moreover, tailwater TDG concentrations were less than forebay concentrations during early June indicating that TDG concentrations in the Columbia River were being reduced by spilling over the deflectors at Chief Joseph Dam.

- TDG saturations at Albeni Falls tailwater station (ALQI) exceeded 110% from about May 6, 2008 to July 29, 2008. Little to no difference in TDG concentrations between the forebay (ALFI) and tailwater (ALQI) stations were noted when Albeni Falls was on free-flow operations with the total river volume passing over the spillway. In general, the greatest increase in TDG saturations between the forebay and tailwater were measured between May 9 and May 16, 2008 during spillway releases of about 26,000 cfs. In general, TDG saturations decrease at Albeni Falls when the spill is spread out over at least 8 of 10 spill bays or when the project operates on free-flow.

- TDG saturations at Libby Dam ranged from about 98% to 112%, with TDG concentrations exceeding 110% between September 8 and 30, 2008. The increase in TDG during non-spill conditions was likely related to a decrease in outflow from Libby Dam resulting in on unit being operated at a low efficiency. To prevent the unit from running too rough, air was injected into the unit resulting in the spike in TDG concentrations measured at the tailwater station.

- Water temperatures at the Chief Joseph Dam forebay (CHJ) and tailwater (CHQW) were greater than 16°C and 18°C (Coleville Tribal temperature standards for above and below Chief Joseph Dam, respectively. See Section 5.4.1) from about mid-July through September 2008 and mid August through September 2008, respectively. Water temperatures at Albeni Falls Dam forebay (ALFI) and tailwater (ALFW/ALQI) were greater than 19°C from about Mid July through the end of August 2008 and exceeded 22°C only on August 18, 2008. Temperatures measured at the Libby Dam tailwater (LBQM) station ranged from about 4°C in April to 15°C in August.

The full QA/QC report on the Seattle District gages can be found in Appendix L.

Part 4 Fish Spill Program

4.1 Spill

Operation of the FCRPS to meet multiple purposes often necessitates spill operations that can result in exceedances of state TDG water quality standards. The Corps, in accordance with the 2004 NOAA Fisheries BiOp and the Corps' 2008 FOP, provides voluntarily spills for fish passage. In addition, spill at Corps projects occurs when there are physical or mechanical circumstances that necessitate spill. For instance, when powerhouse capacity is exceeded, the intertie lines need repair, or unit outages, water is released through the spillway resulting in increased TDG levels.

The NOAA Fisheries 2004 BiOp and 2008 FOP voluntary spill for fish program was implemented consistent with the State water quality standards waiver or criteria adjustment. During the migration season, adjustments were made to the upstream project spill levels to maintain the average of the 12 highest values in 24 hours in project forebays at less than 115% TDG and the average of the 12 highest values in 24 hours in project tailwaters at less than 120%.

The 2008 Fish Operation Plan (FOP) is provided as Appendix C of this report or at http://www.nwd-wc.usace.army.mil/tmt/documents/ops/

4.1.1 Spring Spill

During 2008, there was spring spill at the lower Columbia and Snake River projects as called for in the 2008 FOP. Spring spill began 3 April and continued through 20 June at the Lower Snake River projects. Spring spill began 10 April and continued through 21 June at McNary, John Day, and Bonneville and to 30 June at The Dalles.

The 2008 FOP called for the following spill operations during the spring:

Lower Granite: 20 kcfs, 24 hours per day;

Little Goose: 30% of river flow, 24 hours per day, plus 14 days of spill to the spill cap between 22 April and 15 May;

Lower Monumental: To the spill cap (estimated to be approximately 27 kcfs), 24 hours per day;

Ice Harbor: Spill alternating between 30% of the river flow 24 hours per day or 45 kcfs during the day and up to the spill cap at night;

McNary: 40% of the project outflow.

John Day: 60% of total outflow during the night with no spill during the day from 10 April through 20 April, 30% of outflow from 21 April through 1 May, and alternating between 30% and 40% of total outflow from 21 April through 20 June.

The Dalles: 40% of the project outflow.

Bonneville: To the gas cap up to100 kcfs.

Additional detail is provided in the FOP in Appendix C.

Total river flows remained elevated on the Columbia River from the third week of May to the first week of July when the freshet occurred. Total river flows on the Columbia River during this period were between a daily average flow of 276 and 418 kcfs with an overall daily average flow of 402 kcfs. These flows were lower than 2007 when the daily average flow was between 250 and 300 kcfs. Flow began to taper off in July and August. Total river flows remained elevated on the Snake River from the May to early July when the freshet occurred there. Total river flows on the Lower Snake River during the early May to early July period were between a daily average flow of 62 and 199 kcfs, which is similar to 2006 when the flow was between 83 and 200 kcfs. The TDG exceedances that resulted from these low flows are discussed in Part 5 of this report.

4.1.2 Summer Spill

During 2008, summer spill began 21 June and continued through 31 August at the lower Snake River projects, and McNary, John Day, and Bonneville on the lower Columbia River. Summer spill at The Dalles on the lower Columbia River began 1 July and continued through 31 August

The 2008 FOP called for the following spill operations during the summer:

Lower Granite: 18 kcfs, 24 hours per day;

Little Goose: 30% of river flow, 24 hours per day;

Lower Monumental: 17 kcfs, 24 hours per day;

Ice Harbor: Spill alternating between 30% of the river flow 24 hours per day or 45 kcfs during the day and up to the spill cap at night;

McNary: Spill alternating between 40% and 60% of the project outflow.

John Day: Spill alternating between 30% and 40% of total outflow from 21 June through 18 July, then 30% of outflow from 19 July through 31 August.

The Dalles: 40% of the project outflow.

Bonneville: Spill 85 kcfs during the day and to the spill cap at night from 21 June through 20 July. Spill 75 kcfs during the day and to the spill cap at night from 21 July through 31 August.

Additional detail is provided in the FOP in Appendix C.

Total river flows continued to be high on the Columbia River during July and tapered off August. Total river flows on the Columbia River during July were between a daily average flow of 156 and 327 kcfs with an overall daily average flow of 212 kcfs, which was much higher than 2007 (174 kcfs) or 2006 (184 kcfs). Total river flows on the Columbia River during August were average at 135 kcfs. Total river flows continued to be high in July began to taper off August on the Snake River. Total river flows on the Snake River during the July - August period were between a daily average flow of 26 and 143 kcfs with a summer average flow of 56 kcfs, which is high compared to 2007 (28 kcfs) and 2006 (37 kcfs). The TDG exceedances are discussed in Part 5 of this report.

4.1.3 Spring Creek Hatchery Spill

Each year the Spring Creek National Fish Hatchery releases approximately 7.5 million Chinook salmon in March. In 2008, to reduce overcrowding in the juvenile bypass system and to accommodate passage of the March release past Bonneville Dam, the project provided spill of approximately 36.4 kcfs from 2359 hours on March 6 until 0600 hours on March 10. Throughout this operation, spill discharge from Bonneville Dam ranged from 34.6 to 38.2 kcfs, with an average of 36.7 kcfs.

During this operation, hourly depth compensated TDG levels measured at the Warrendale TDG monitoring site ranged from 100.0% to106.1% with an average of 102.4%. Depth-compensated TDG levels exceeded the maximum 105.0% level specified for Ives Island Complex Chum salmon redds for a total of two hours (1600-1800 hours) on the afternoon of March 8 and one hour (1600-1700 hours) on the afternoon of March 9. Minimum Bonneville project tailwater elevation to protect Chum redds was specified to be at or above a minimum of 12.5 feet measured at Tanner Creek from 2359 hours on March 6 until 1334 hours on March 7. Actual tailwater elevation during this time ranged from 12.1 - 15.9 feet. On March 7 at 1334 hours, the Bonneville project minimum tailwater specification was amended to a minimum of 13.0 feet through the end of the spill operation for the March Spring Creek release. Actual tailwater elevation from 1334 hours on March 7 through the end of the spill operation on March 10 at 0600 hours ranged from 13.0 - 14.4 feet.

4.1.4 Fish Test Operations

During 2008, there were five fish test operations that affected spill for fish passage described in the 2008 FOP. The five fish tests were conducted as part of fish passage research studies. These research studies were developed and coordinated through the Anadromous Fish Evaluation Program Studies Review Work Group (AFEP-SRWG) with

NOAA Fisheries providing concurrence on the final study plan for each test conducted. The special spill operations were: 1) Ice Harbor fish passage and survival test; 2) John Day top spillway weir test; 3) McNary top spillway weir test; 4) Lower Monumental removable spillway weir test; and, 5) Little Goose fish passage and survival test.

Ice Harbor Fish Passage and Survival Test

A fish passage and survival test was conducted at Ice Harbor from 30 April to 19 July. The test consisted of spill alternating between two days of spilling 30% of the total project discharge 24 hours a day and two days of spilling to the 120% spill cap during the night and 45 kcfs during the day. The purpose of the fish survival test was to evaluate the fish passage and survival under two different spill levels. See Appendix D for more information on the fish test.

The test resulted in spill ranging from 15 to 169 kcfs, which resulted in TDG levels fluctuating between 112.2% and 130.0% as shown on the weekly graphs in Appendix E. (April report, Figures 4, 8, 16, and 24; May June, and July reports, Figures 4, 12, 20 and 28; August report, Figures 4, 12, 20, 28 and 36).

John Day Top Spillway Weirs' Test

Two Top (or Temporary) Spillway Weirs (TSW) were evaluated at John Day from 2 May to 19 July with spill alternating between 30% and 40%, respectively, of total river discharge in a randomized 2-day treatment, 4-day block design. The purpose of the evaluation was to estimate fish survival and passage efficiency under two spill levels with the TSWs in place. See Appendix D for more information on the TSW evaluation.

The evaluation resulted in spill levels ranging from 28 to 240 kcfs, which produced TDG levels fluctuating between 115% and 125% as shown on the weekly graphs in Appendix E. (April report, Figures 10, 18, 26, and 34; May June, and July reports, Figures 6, 14, 22 and 30; August report, Figures 6, 14, 22, 30 and 38).

McNary TSW Test

A TSW test was conducted at McNary from 22 June to 31August with spill levels alternating between 40% and 60%, respectively, of total river discharge in a randomized 2-day treatment, 4-day block design. The purpose of the top spillway weirs test was to evaluate fish survival and passage efficiency under different the spill levels; 40% of the river flow vs. 60% of the total river flow. See Appendix D for more information on the fish test.

The test resulted in spill levels ranging from 18 to 229 kcfs which produced TDG levels fluctuating between 113.9% and 120.6% as shown on the weekly graphs in Appendix E. (April report, Figures 9, 17, 25 and 33; May, June, and July reports, Figures 5, 13, 21, and 29; August Report, Figures 5, 13, 21, 29 and 37).

Lower Monumental Removable Spillway Weir Test

A Removable Spillway Weir (RSW) test was conducted at Lower Monumental from 30 April to 1 June with spill patterns alternating between two days blocks of either a bulk or a flat spill pattern. The purpose of the RSW test was to evaluate juvenile fish passage and survival at the project under the two conditions with the RSW in place.

The test resulted in spill levels ranging from 20 to 122 kcfs, which produced TDG levels fluctuating between 112.9% and 126.7% as shown on the weekly graphs in Appendix E. (April report, Figures 3, 7, 15, 23 and 31; May, June and July reports, Figures 3, 11, 19 and 27; August report, Figures 3, 11, 19, 27 and 35).

Little Goose Fish Passage and Survival Test
An adult fish passage test was conducted at Little Goose from 3 April to 31 August with spill patterns alternating between two days blocks of either "bulk", "uniform", or "alternative" spill pattern. The purpose of the test was to evaluate adult passage under the three different spill patterns.

The test resulted in spill levels ranging from 7 to 130 kcfs, which produced TDG levels fluctuating between 107.8% and 128.1% as shown on the weekly graphs in Appendix E. (April report, Figures 2, 6, 14, 22 and 30; May, June and July reports, Figures 2, 10, 18 and 26; August report; Figures 2, 10, 18, 26 and 34 of the August reports).

4.1.5 Turbine Outages that Effect Spill

On a weekly or daily basis, unit outages will affect the spill volume at the projects. There are fourteen turbines on the Columbia or Snake River that were out of service from two months to two years:

- Lower Granite: Unit 2 was out of service throughout entire year and will remain so into 2009 due to a linear cavitation and generator rewind of the turbine and unexpected damages.
- Little Goose: Unit 6 was forced out of service from April through September due to a winding repair.
- Ice Harbor: Unit 1 was out from August through September for main unit strainers repair. Unit 6 was forced out from April through May for a high gas readings/T6 repair.
- McNary: Units 5 was out from July through September for a 9-year overhaul. Unit 7 was out during July for an external thrust bearing oil cooler repair.
- John Day - Units 1 and 3 were out of service for overhaul from 28 July through 4 September for their 9-year overhaul. Unit 9 was out of service from 28 July to 11 September.
- The Dalles: Unit 4 was out of service from March through June due to a cavitation repair. Unit 22 was out of service from June through August for 5-year blade cavitation seals and servo motors repair.
- Bonneville: Unit 7 has been out of service through out the entire year due to a turbine rehabilitation and stator repair. Unit 3 was out of service from April through May for a five year overhaul, and turbine obstructions. Unit 1 was out of service from July 5 through August 20 for a five year overhaul and turbine

There were fourteen unit outages at seven projects that continued between two months and 2 years in duration. These unit outages resulted in additional involuntary spill but not enough to cause TDG exceedances. Only the Bonneville unit outages that occurred on 12 May resulted in a TDG exceedance.

4.1.6 Voluntary Spill

During most migration seasons, there is voluntary and involuntary spill on the lower Columbia and Snake Rivers. Table D-12 provides the total outflow (sum of the eight project outflows) for each year with the nine-year total outflow average. Based on the total outflow amounts, the 2002, 2006 and 2008 water years had high amount of total project discharge and a larger than average amounts of involuntary spill. The amount of runoff is the primary factor that determines how much voluntary and involuntary spill will occur, although unit outages can also play a role.

During 2008, the voluntary spill called for in the FOP occurred from 3 April to 31 August at the lower Snake River projects and from 10 April to 31 August at the lower Columbia projects. Table D-9 in Appendix D provides the exact amount of BiOp/FOP or voluntary spill that occurred at the various projects. Table D-10 provides the total outflow from each project and a total of all the projects.

FOP Spill Amounts Calculated

In 1998, the Corps RCC staff developed a BiOp spill program for daily operational monitoring of BiOp spill and to calculate the amount of BiOp spill that should occurs at the various projects. Since the spill operation at many of the projects change each year, the program that calculated BiOp spill must be modified to calculate the corresponding FOP spill. The amount of FOP spill is shown on Tables D-1 through D-8 and in graphs included in the court reports (Appendix E). For more information, the FOP spill can be compared to the TDG levels shown in Appendix C, which contains graphs of spill, flow, and TDG.

4.1.7 Involuntary Spill

Involuntary spill occurred at the lower Columbia River projects from 17 May through 4 July and from 8 May through 2 July on the lower Snake River. Lower Granite had the most involuntary spill of any of the lower Snake River projects, up to 109 kcfs from 8 May to 1 July (55 days) with an average involuntary spill of 38 kcfs per day. Little Goose involuntary spill was up to 60 kcfs from 17 May to 30 June (46 days) with an average involuntary spill of 14 kcfs per day. Lower Monumental involuntary spill was up to 60 kcfs from 18 May to 28 June (42 days) with an average involuntary spill of 16 kcfs per day. Ice Harbor involuntary spill was up to 63 kcfs from 8 May to 2 July (56 days) with an average involuntary spill of 21 kcfs per day. Bonneville had the most involuntary spill of any of the Lower Columbia River projects, up 137 kcfs from 18 May to 4 July (48 days) with an average involuntary spill of 72 kcfs per day. McNary involuntary spill was up to 105 kcfs from 18 May to 3 July (47 days) with an average involuntary spill of 48 kcfs per day. John Day involuntary spill was up to 44 kcfs from 24 May to 1 July (40 days) with an average involuntary spill of 6 kcfs per day. The Dalles involuntary spill was up to 41 kcfs from 19 May to 1 July (45 days) with an average involuntary spill of 7 kcfs per day.

The FOP spill tables in Appendix D indicate the days and amounts spilled at the lower Columbia and Snake River projects. As Table D-10 shows, actual spill was higher than the estimated FOP spill because of the large amount of involuntary spill that occurred with the high runoff.

Involuntary Spill Effects on TDG:
The impact of high flows on TDG levels was significant because of the duration of the high flows and the shape of the runoff. The high freshet flows persisted for 56 days with one single large peak that began 8 May and lasted until 4 July. The runoff peak occurred from 19 May to 6 June with daily average flows between 373 and 419 kcfs on the lower Columbia River, which is high compared to previous years. As a result, there were 515 TDG exceedances system-wide with 262 TDG exceedances on the lower Snake River (Appendix F, Table F-3A) and 250 TDG exceedances on the lower Columbia River (Appendix F, Table F-3B). Of the 515 TDG exceedances system-wide, 398 were due to high runoff flows and flood control efforts. More detailed information on the project specific TDG exceedances is provided in Part 5 of this report.

Six of the eight lower Columbia and Snake River projects exceeded the hourly value of 125% TDG at one time or another. As shown in Appendix F Table F-6, there were a total of 668 hours of TDG exceedances over 125%. The highest hourly reading was at Little Goose tailwater with 142.7% as shown on Table F-6 and Table F-4 in Appendix F. Graphs of the Snake and Columbia River projects' 12-hour average TDG levels shown in Appendix D illustrate the impact of involuntary spill levels on TDG levels during the freshet period. More detailed information on project specific TDG exceedance of the 125% TDG standard is provided in Part 5 of this report.

4.1.8 2008 Dworshak Releases

Throughout the 2008 water year, releases from Dworshak were managed for both flow augmentation and temperature control. From mid-September through June, releases from Dworshak were adjusted to meet the temperature needs of the Dworshak hatchery located approximately two miles downstream. From the beginning of July through mid-September, releases from Dworshak Dam were managed to provide flow augmentation and to moderate temperature of the lower Snake River, especially Lower Granite tailwater. Appendix I graphs show temperatures for the lower Snake projects. Water releases from Dworshak Dam for flow augmentation/temperature moderations began on 7 July when Dworshak forebay elevation was at 1599.9 ft and continued through 28 September, when the forebay elevation of 1520.0 ft was reached. A full discussion of Dworshak releases for flow augmentation and temperature control are provided in Appendix I.

4.2 Statistical Evaluation of the SYSTDG Model for 2008

During the 2008 migration season, the RCC Water Quality Unit used the SYSTDG model to forecast the TDG levels at the Corps Columbia and Snake River projects for the purpose of setting daily spill caps. SYSTDG is a tool that the Corps used to estimate TDG pressures resulting from project operations on the Columbia, Snake, and Clearwater rivers. The parameters that SYSTDG incorporates into its forecast are: total river flow; spill; wind; water temperature; forebay and tailwater elevations; barometric and total gas pressures; and tributary flow data. In an effort to quantify the uncertainty of SYSTDG estimates and improve modeling accuracy and reliability, a statistical evaluation of the predictive errors was performed on observed TDG levels during the 2008 fish passage season on the Columbia and Snake rivers. This evaluation was conducted by comparing SYSTDG-calculated TDG to observe gas pressures measured by the fixed monitoring stations (FMS) located in the forebays and tailwaters of Corps operated dams within the Columbia Basin. The dams of interest included Bonneville, The Dalles, John Day, McNary, Ice Harbor, Lower Monumental, Little Goose, Lower Granite and Dworshak.

The RCC Water Quality Unit considered the statistical evaluation of SYSTDG performance in previous years (2004 through 2008) to be highly useful in continuing to establish the model as an effective tool in managing spill and will help identify areas for future improvements. The following is a short summary of the SYSTDG statistical evaluation for 2008 as provided by the Corps' Engineering Research Development Center (ERDC). The full statistical evaluation can be found in Appendix G.

4.2.1 The Predictive Error for each FMS

A statistical evaluation of the predictive errors was performed on observed TDG levels during the 2008 fish passage season on the Columbia and Snake rivers in an effort to quantify the uncertainty of SYSTDG estimates and improve modeling accuracy and reliability. This evaluation was conducted by comparing SYSTDG-calculated TDG pressures to observed TDG pressures measured on the FMS located in the forebays and tailwaters of Corps operated dams within the Columbia Basin.

SYSTDG simulations were run for the entire 2008 spill season for one project and river reach at a time so that predictive errors could be calculated independently for each dam and river reach. The difference between the hourly observed and calculated TDG pressure or saturation was the definition used for the predictive error where positive errors reflect over-estimation of observed conditions and negative values reflect an under-estimation of observed conditions. The tailwater FMS comparison was dependent upon the location of the sampling station relative to the mixing zone of project releases. In most cases, the tailwater FMSs are located in either spillway flows undiluted from powerhouse flows or in mixed river waters. The summary of predictive error was limited to period of active spillway operations at each project at the tailwater FMS. The TDG pressures transported to the forebay of the next downstream dam were used to determine the predictive error during the period from April 1-August 31 for the Snake River and lower Columbia River projects. In each reach simulation the observed temperatures and total pressures in the forebays were used as boundary conditions for the simulation. Where forebay and tailwater temperatures were different by over 0.3° C, the observed forebay TDG pressure was approximated by linearly interpolating between total pressure observations where temperatures were within 0.3°C. A detailed description of model input parameters and coefficients can be found in the SYSTDG user's manual (USACE, 2004).

TABLE 3

Statistical summary of the predictive errors of the observed and calculated total dissolved gas pressures at forebay fixed monitoring station, April 1-August 31, 2008.

Parameters		Predictive Error at Forebay FMS* (mm Hg)							
Station		**LGSA**	**LMNA**	**IHRA**	**MCNA**	**JDY**	**TDA**	**BON**	**CWMW**
Number of		3522	3638	3638	3672	3672	3670	3646	3627
Average		-5.5	0.8	-1.4	-0.5	6.8	-6.1	4.1	6.6
Standard Deviation		16.2	12.3	9.8	11.0	12.8	12.2	7.4	10.4
Maximum		34.0	39.6	29.4	33.8	72.5	45.0	38.7	44.9
Minimum		-68.3	-33.2	-35.5	-61.9	-13.1	-70.5	-11.4	-17.5
TDG Predictive Error for Percentile Occurrence (mm Hg)	**5%**	-37.5	-18.6	-18.3	-17.4	-8.0	-27.8	-6.8	-7.2
	10%	-29.4	-14.7	-14.6	-12.6	-6.0	-23.4	-5.0	-5.0
	25%	-12.3	-7.9	-7.8	-6.1	-2.5	-13.7	-1.4	-1.2
	50%	-3.0	0.2	-0.4	-0.3	4.0	-3.1	3.2	4.6
	75%	4.3	8.6	5.7	6.0	13.0	1.9	8.5	13.2
	90%	13.0	16.4	9.8	12.8	22.4	6.4	14.5	20.8
	95%	18.0	22.3	12.6	16.5	30.8	10.6	17.4	25.9

*Predictive error is the observed minus calculated TDG pressure where negative values reflect an overestimation and positive values reflect an underestimation.

TABLE 4

Statistical summary of the predictive errors of the observed and calculated total dissolved gas pressures at tailwater fixed monitoring stations, April 1-August 31, 2008.

Parameters		Predictive Error at Tailwater FMS* (mm Hg)									
Station		**DWQI**	**LGNW**	**LGSW**	**LMNW**	**IDSW**	**MCPW**	**JHAW**	**TDDO**	**CCIW**	**WRNO**
Number of		2013	3149	2561	2794	2149	1816	1462	3672	2658	741
Average		-7.3	5.2	3.8	4.2	-2.4	-0.5	0.6	-0.6	0.2	4.3
Standard Deviation		14.3	11.3	9.4	14.7	6.8	7.8	11.9	9.9	18.0	10.2
Maximum		72.5	45.9	48.6	60.1	20.2	30.0	34.8	47.3	39.1	36.6
Minimum		-74.5	-23.0	-47.4	-41.0	-26.2	-26.3	-24.3	-55.8	-64.5	-60.7
TDG Predictive Error for Percentile Occurrence (mm Hg)	**5%**	-23.1	-11.4	-10.3	-15.7	-14.2	-12.9	-15.8	-16.5	-40.6	-9.1
	10%	-20.1	-8.9	-5.1	-11.2	-10.7	-10.8	-13.7	-10.4	-35.8	-5.2
	25%	-15.7	-1.7	-0.4	-4.7	-6.2	-6.0	-10.3	-5.0	1.2	-0.1
	50%	-11.0	4.6	4.0	1.8	-2.3	-0.2	-0.4	0.0	5.3	4.9
	75%	1.5	10.1	8.8	9.3	1.4	4.7	11.1	4.5	9.9	10.1
	90%	14.9	19.0	13.8	26.5	6.1	9.7	16.5	9.1	15.1	14.1
	95%	16.9	27.6	17.9	35.8	9.6	11.8	20.0	12.5	20.2	17.2

*Predictive error is the observed minus calculated TDG pressure where negative values reflect an overestimation and positive values reflect an underestimation.

4.2.2 Highlights of Statistical Evaluation

The following are some highlights from the statistical evaluation:

- In general, the predictive errors at the forebay station (Tables G5 and G6 in Appendix G) were similar to errors estimated at tailwater stations (Tables G7 and G8 in Appendix G). The average predictive errors at forebay stations were less than 1 percent of saturation with the exception of John Day Dam. The overestimation of forebay TDG pressures at John Day Dam was attributed to misrepresenting either the production of TDG conditions at McNary Dam or the dissipation rate during transport to John Day Dam. The correlation between strong winds and declining TDG pressure at forebay stations was again evident during the 2008 spill season. In several reaches, the considerations of alternative weather station data for wind may improve the estimation of TDG off-gassing during passage through a given river reach.

- The largest average predictive error determined at a tailwater FMS was observed below Dworshak Dam. The lack of a forebay FMS at Dworshak contributed to the biased estimates of TDG pressure in the tailwater at Dworshak Dam. The errors in predicting TDG saturation below a spillway are likely associated with the TDG heterogeneities generated in spillway flows and monitored at many tailwater FMS, the timing and duration required to establish steady-state TDG levels at monitoring stations, and the application of accurate spill pattern operations. The standard deviation of predictive error at the tailwater stations ranged from 6.8 mm Hg at Ice Harbor Dam tailwater station IDSW to 18.0 mm Hg at the Bonneville tailwater station (CCIW). The large standard errors below Bonneville Dam result from biased observed values at higher spill rates.

- The TDG production characteristics observed at Bonneville Dam tailwater station (CCIW) during the 2008 spill season were highly non-linear with little change in TDG saturation for spill rates above 130 kcfs. The SYSTDG model over-estimated the TDG response at the CCIW station during higher spillway flows. The model estimates were based on the average cross sectional response observed in the spillway exit channel during sampling in 2002. The sampling bias under-estimating the TDG loading at CCIW during higher flows during the 2002 study is likely to be present under existing conditions because the spill pattern has not changed for flows above 100 kcfs since 2002. The higher production of TDG saturation predicted by the model was consistent with TDG levels observed downstream in the Columbia River. The tailwater spill capacity as limited by TDG saturation of 120%was observed to fall below levels seen in previous years at Bonneville Dam because of the high total river flow and associated tailwater elevation during much of the 2008 spill season. The estimates of TDG pressure at the Camas/Washougal FMS during August of 2008 were unexpectedly larger than seen in previous years. The low tailwater elevations may have resulted in higher TDG generation associated with the Bonneville second powerhouse corner collector outfall.

- The TDG predictions at The Dalles Dam and throughout the Bonneville pool proved to be one of the more reliable reaches in the study area. The standard error observed at the Dalles tailwater station was estimated to be 10.2 mm Hg while the corresponding standard error in the forebay of Bonneville Dam was only 7.4 mm Hg. The cause for the poorer estimates of tailwater TDG levels compared to downstream estimates in the forebay of Bonneville Dam were likely associated with the greater occurrences of abrupt changes in TDG pressure caused by operation changes at the tailwater station. It is important to recognize that the tailwater FMS below The Dalles Dam resides in mixed waters influenced by both powerhouse and spillway flows when interpreting the overall system impact on TDG loading in the lower Columbia River. It should be noted that the estimated TDG content in spill water undiluted from powerhouse flows remained well above 120% for the duration of the fish passage season. The higher river flows during 2008 resulted in spill at The Dalles Dam exceeding 126 kcfs requiring spill bays outside of the spillwall (bays 1-6) being active about 25 percent of the time. There was no indication that the TDG generation properties at The Dalles Dam changed noticeably during these spill patterns.

- The structural configuration and spill pattern at John Day Dam was changed during the 2008 spill season incorporating two spill bays with TSWs. The spill pattern called for higher discharges through these two spill bays. The relationship between TDG generation and spillway discharge at John Day Dam changed significantly during the 2008 compared to previous years. The TDG generation model maintained the same functional form but the spill pattern was altered resulting in a pattern where TDG pressures continuously increased as a function of spillway discharge. The pattern prior to 2008 consisted of a range of spill discharge where the TDG generation decreased as the spill pattern transitioned from a bulk to a uniform pattern. There was a tendency for the SYSTDG model to underestimate the TDG pressure at the tailwater FMS during lower spill discharges. This under-estimation of TDG pressure may have resulted from the increasingly non-uniform spill pattern caused by the TSWs. The SYSTDG model over-predicted the TDG pressures arriving at The Dalles Dam particularly during high spill events at John Day Dam. An entrainment coefficient used by SYSTDG was increased to 0.75 based on the observed conditions throughout the month of April. However, this parameterization of entrainment flow over predicted the TDG loading at John Day Dam during the higher flows and spillway discharge during May and June. An entrainment coefficient of 0.35 is recommended for characterizing the TDG loading at John Day Dam based on a review of

TDG data collected in the Columbia River downstream of John Day Dam during the 2008 spill season.

- The operations at McNary Dam involved spilling water through two of TSWs throughout the entire fish passage season. The location of these structures changed in 2008 being located in spill bays 19 and 20. The spillway capacity as limited by the tailwater TDG saturation of 120% was observed to be slightly higher at about 180 kcfs during 2008 when compared to conditions in 2006. The TDG levels at the tailwater station increased in magnitude when spill levels dropped below 80-90 kcfs. This property was likely related the mixing zone from the TSW releases reaching the north shore during lower spillway discharges. McNary Dam spilled more water than any project except Bonneville Dam on the Columbia River in 2008. The TDG estimates in the forebay of John Day Dam were systematically under-estimated during the 2008 spill season. The mean and standard error in the forebay of John Day Dam were 6.8 and 12.8 mm Hg, respectively. The time of travel in John Day pool is the longest of any of the reaches modeled in this investigation. This long duration can amplify errors associated with wind driven degassing. The prediction of in-pool degassing in the John Day pool can be improved by applying a different weather stations wind field and exchange coefficients. The weather data at The Dalles municipal airport was applied to the John Day pool in 2008. In the future, weather data from the Tri-cities area should be used to estimate the off-gassing processes in the John Day pool.

- The SYSTDG model of Ice Harbor TDG generation as observed at the tailwater FMS had the smallest standard error of any of the projects studied. Ice Harbor Dam continues to have the smallest TDG uptake for a comparable spill discharge of any project on the Columbia or Snake Rivers. Ice Harbor Dam spilled the highest percentage of total river flow of 58% of any project in the study area. The spill capacity as limited by the 120%TDG saturation criterion was as high as 90 kcfs. The combination of spillway flow deflectors with a shallow tailwater channel are thought to account for this efficient TDG exchange property. The operation of the spillway at Ice Harbor Dam in 2008 involved biological testing of the RSW where day-to-day changes in total spill discharge were often large. The maximum spill discharge at Ice Harbor Dam in 2008 was 170 kcfs resulting in a tailwater TDG saturation of 135% which was the highest TDG saturation observed in the study area.

- The TDG production model for Lower Monumental Dam produced the highest standard error on the Snake River that typically under-estimated the TDG saturation observed at the tailwater FMS. The complexity in the TDG exchange characteristics includes the application of multiple spill patterns and the entrainment of powerhouse flows into spillway flows. The scheduling of a bulk spill pattern resulted in higher TDG pressures when compared with the standard spill pattern. An alternative TDG production formulation was developed consisting of the power function of tailwater depth of flow and the specific spillway discharge. The observed TDG saturation at the tailwater FMS was found to be a function of the forebay TDG saturation for small total river flows. The frequency of hourly TDG supersaturation above 115% at the Ice Harbor forebay station was the highest of the four Snake River projects. The spill policy at Lower Monumental Dam resulted in the TDG saturation in the Ice Harbor forebay to exceed 115% over 33.8% of the time.

4.2.3 Future Improvements Identified

The following improvements and maintenance activities to the SYSTDG model are recommended for the next year.

- The TDG production characteristics in Little Goose and Lower Monumental pools during high forced spill conditions will require additional field sampling to supplement data from the FMS. It is not possible to determine with significant confidence if the predictive errors in these pools is attributed to the rate of off-gassing or rate of TDG production. These events generate TDG levels that are known to cause GBT in juvenile salmonid and steelhead salmon.

- The description of TDG exchange at all projects within the study area should be updated to reflect the current spill patterns and structural configurations. The inclusion of raised spillway weirs (RSWs or TSWs) or repositioning of TSWs is expected to continue on a regular basis.

- The SYSTDG decision support system will continue to be improved to consider alternative spill patterns into predictions of TDG loading in the Columbia River basin.

- As additional weather stations provide real time data, continue to update the SYSTDG model to utilize these data.

- The identification of consistent sampling bias at FMSs should be documented and incorporated into management activities.

- The uncertainty of TDG predictions should be factored into a risk-based management policy for spill.

Part 5 TDG Exceedances

5.1. Change in TDG Exceedance Calculation Methods

In previous years, the States of Oregon and Washington specified the method of calculating the "daily % TDG" as an average of the 12 highest hourly readings in a given day. In November 2006, the WDOE modified their water quality standards for surface waters to include a change in the method of calculating % TDG. The new method of calculating the % TDG involves using a running consecutive 12-hour average. Specifically, each hour of a given day is end of a 12-hour interval. The daily high consecutive 12-hour TDG level determined as the highest of the average value of each 12-hour interval for each hour of the day. This results in a calculated daily value that can span over two days. For the remainder of this report, this method shall be referred to as the "Washington method." It was agreed that the Corps would evaluate the new Washington method of calculating the consecutive 12-hour average in 2008 and compare it again the Oregon method of high 12-hour average. The previous method, which is still specified by the State of Oregon, shall be referred to as the "Oregon method" for the remainder of this report. An evaluation and discussion of the two methods are provided in section 5.3 of this report.

5.2 TDG Exceedances – Oregon Calculations

5.2.1 115% and 120% TDG Exceedances

The Corps tracks the number of high 12 hour average TDG exceedances during spill season. During the 2008 spill season, Washington and Oregon TDG criteria were exceeded 515 days at the projects on the lower Columbia and Snake rivers out of 2504 days ([number of TDG gages] x [days in spill season, 3 April through 31 August]). The 515 high 12-hour average TDG exceedances are far above the 266 ten-year average TDG exceedances for a spill season. Table 5 provides a summary of TDG exceedances for 1999 through 2008 spill seasons. The 515 high 12-hour averages of TDG exceedances during 2008 spill season include both voluntary and involuntary TDG exceedances.

As indicated in Table 5, the Camas/Washougal, Cascades Island, Ice Harbor forebay, and Lower Monumental forebay FMS had the highest number of high 12-hour average TDG exceedances during 2008 and were the most difficult to maintain below the 115% or 120% TDG standard.

Most TDG exceedances during the 2008 spill season were recorded at Camas/Washougal (68), Bonneville tailwater at Cascades Island (56), Ice Harbor forebay (55), and Lower Monumental forebay (54). The remaining FMS gages recorded TDG exceedances ranging from 0 to 35.

The Camas/Washougal FMS historically records a higher number of exceedances than other FMS locations. The 2008 WY was no exception. With such high flows, it was expected that the Cascades Island FMS, would have the second most TDG exceedances, as indicated in Table 5. The Bonneville unit outages exacerbated the high flow situation so that TDG exceedances occurred for many weeks. The Ice Harbor forebay gage registering the third most TDG exceedances and the Lower Monumental forebay gage registering the fourth most TDG exceedances is typical, as indicated in Table 5. For further discussion of the individual gages that have high TDG exceedance, see section 5.2.5 of this report.

TABLE 5
1999 - 2008 SPILL SEASONS
NUMBER OF DAILY TDG EXCEEDANCES
OF THE HIGH 12-HOUR AVERAGE
(OREGON METHOD)

Water Quality Gages	2008	2007	2006	2005	2004	2003	2002	2001	2000	1999	10 year Avg
	Qty.	Qty.	Qty.	Qty.	Qty.	Qty.	Qty.	Qty.	Qty.	Qty.	Qty.
Lower Granite Forebay	0	0	0	0	0	0	0	5	2	0	0.7
Lower Granite Tailwater	35	0	28	0	0	15	17	0	4	15	11.4
Little Goose Forebay	34	0	24	0	3	10	17	0	2	39	12.9
Little Goose Tailwater	23	0	19	0	0	6	6	0	9	6	6.9
Lower Monumental Forebay	54	11	56	6	1	19	49	0	28	44	26.8
Lower Monumental Tailwater	32	7	29	7	1	10	6	0	12	26	13
Ice Harbor Forebay	55	31	51	3	4	35	24	0	34	44	28.1
Ice Harbor Tailwater	31	0	22	3	2	4	6	0	4	12	8.4
McNary Forebay - WA	21	6	31	8	10	24	43	1	14	22	18
McNary Forebay - OR	--	--	--	11	23	32	45	5	22	19	15.7
McNary Tailwater	28	1	32	1	7	12	31	0	17	50	17.9
John Day Forebay	14	0	20	2	0	10	11	0	1	8	6.6
John Day Tailwater	17	3	38	3	0	0	29	0	12	43	14.5
The Dalles Forebay	17	8	40	6	5	11	18	0	5	1	11.1
The Dalles Tailwater	2	0	10	0	0	4	11	0	5	5	3.7
Bonneville Forebay	27	3	51	3	1	17	30	0	14	19	16.5
Cascade Island *	57	0	61	0	---	---	---	---	---	---	29.5
Warrendale	--	--	--	---	0	1	19	0	6	2	2.8
Camas/Washougal	68	29	63	16	14	33	65	2	58	51	39.9
Total Number of Exceedances	**515**	**99**	**575**	**69**	**71**	**243**	**427**	**13**	**249**	**406**	266.7

* Four year average

5.2.2 125% TDG Exceedances

During the 2008 migration season, there were 668 hourly TDG exceedances of the either the Oregon or Washington state standards of 125% TDG (a one hour standard in Oregon and a two hour standard in Washington). 2008 had the highest number of 125% hourly TDG exceedances of the last eight years since tracking of the hourly exceedances began in 2001 (Table F-5 in Appendix F). The effect on involuntary spill due to high runoff resulted in 652 125% exceedances of the Oregon standard. This was the number one factor that contributed to number of these exceedances. Aspects of the high runoff that influenced the exceedance of the hourly/two-hourly criteria were: 1) duration of the runoff; 2) shape of the runoff; and 3) the quantity of the runoff. In order to understand these three factors, it is helpful to compare the 2008 water year to the 2006 water year. These years had similar runoff quantities. In 2008, involuntary spill lasted up to 56 days compared to the 2006 water year, where involuntary spill lasted up to 71 days. This shows that the runoff came off at a lower level for a longer period of time in 2006 as compared to 2008. The 2008 runoff was more intense for a shorter period of time, which resulted in more 125% hourly TDG exceedances. In 2006, high runoff occurred in April and through June. Because high runoff on the Lower Columbia in 2006 occurred before 10 April, some involuntary spill did not result in excessively high spill or TDG levels. In 2008, high runoff occurred in May through early July allowing the full effects of involuntary spill on TDG levels, resulting in more 125% hourly TDG exceedances.

In 2008, eleven special spill operations to pass woody debris on both the lower Columbia and lower Snake rivers occurred that contributed to the number of 125% TDG exceedances. Debris in project forebays negatively impacts project operations and can have a deleterious effect on fish, as the debris often accumulates in or near juvenile bypass systems and on dewatering screens. The buildup can cause injury, and sometimes mortality, of juvenile salmonids. Typical debris spill operations require opening individual spillbays far enough to allow floating debris to pass under the gates. Opening spill gates to the extent necessary to pass the floating debris can elevate TDG levels for short periods of time during the operation, usually from one to four hours.

Projects conducting spill operations to pass debris included: Lower Granite – May 21; Little Goose – May 28; June 5, 25; July 7; Lower Monumental – July 8; Bonneville – May 8, 12, 27 and June 2, 3

TDG levels exceeded 125% due to debris spill a total of 16 hours. The TDG levels from these debris spills ranged from 123% to 138% TDG.

5.2.3 Comparison of Annual Daily Exceedances

A comparison of the 2008 daily TDG exceedances to the ten-year average shows that 2008 had a high number of daily exceedances on an average. As indicated in Table 5, there were 515 daily TDG exceedances in 2008. As indicated in Table 6, the nine year average is 251 daily TDG exceedances. By comparison, 2008 had twice the number of daily exceedances as compared to the nine-year average. This high number of daily TDG exceedance is attributed to high flows and the shape of the runoff. Even though the April through July percent of normal runoff at The Dalles was in the “slightly below average” range with 93% of normal (1971-2000), the April runoff was very low and May and June runoff was high, resulting in a high number of daily exceedances. The shape of the runoff can be observed in the percentages of normal that are shown on Table 1.

TABLE 6
SUMMARY COMPARISON OF DAILY TDG EXCEEDANCES WITH PREVIOUS YEARS

Year	Days In Spill Season	Number of Days of Exceedances	Percent of Days Exceeding TDG Standard (%)	Percent of Days Consistent With TDG Standard (%)	% of Normal runoff at TDA [1]
2008	2504	515	20.6	79.4	92.5
2007	2504	99	4.0	96.0	89.2
2006	2504	575	23.0	77.0	131.4
2005	2754	69	2.5	97.5	93.5
2004	2754	71	2.6	97.4	95.3
2003	2754	243	8.8	91.2	100.8
2002	2754	427	15.5	84.5	119.3
2001	2754	13	0.5	99.5	66.9
2000	2754	249	9.0	91.0	112.7
Average	**2671**	**251**	**9.6**	**90.4**	**100.2**

[1] The Dalles Jan-Jul Avg (1971-2000) =107.3 MAF

Note: Number of spill days are based on 18 gages X 153 days from April 1 - August 31 (except 2006 & 2007 had 17 gages and spill season started Apr 3 for Snake R and April 10 L.Col R).

5.2.4 Type of Daily TDG Exceedances

Since 2003, the Corps has been requested to track the causes of daily high 12-hour average TDG exceedances. To date, 14 causes have been identified and are shown on Table F-1 of Appendix F. The Corps tracked the daily TDG exceedances types for the forebay and tailwater of each Corps project during the 2008 spill season. The types of exceedances represent conditions that caused daily TDG exceedances. The 2008 tracking results are shown on Table 7. Table 7 also provides a summary of the types of daily exceedances tracking results from 2003 through 2008 spill seasons. A more detailed list of when and where the daily exceedance types occurred is provided in Table F-2 in Appendix F. Tables F-3A and F-3B of Appendix F provide the total number of daily TDG exceedances types at each project. The daily exceedance type designation given to each TDG exceedance is based on the Corps subjective determination of causation.

During the 2008 migration season, TDG exceedances were attributed to several causes and they are listed in order of highest number to lowest number of occurrences in Table 7:

1. The high runoff flows and flood control operations (400 exceedances);
2. Uncertainties associated with applying the spill guidance criteria (64 exceedances);
3. High TDG levels coming from the Mid-Columbia River dams (21 exceedances);
4. Exceedance due to sharp rise in water temperature (a 1.5^{o}F or greater change in a day (12 exceedances);
5. The FMS gage malfunctioning causing the gage to register high TDG levels. (10 exceedances);
6. Bulk spill pattern being used which generated more TDG than expected. (5 exceedances);
7. Mechanical problems (gate was stuck open, passing debris etc.) (1 exceedances);
8. Unit outages during repair or maintenance (1 exceedances);

Certain trends were observed from the 2003 – 2008 TDG exceedances tracking data as summarized in Table 7. For example, the types of exceedances listed in Table 7 typically show up every year. High flows, high temperature spikes, malfunctioning gages and unit outages are a normal part of reservoir operations. Efforts continue to be made to reduce daily exceedances when possible.

The majority (77.5%) of the 515 TDG exceedances were caused by the high runoff flows and flood control operations in 2008. Because the shape of the runoff was one intense peak, the flows were high for a long time during the freshet and resulted in many days of involuntary spill.

TABLE 7
2003-2008 SPILL SEASONS
TYPES AND NUMBERS OF TDG EXCEEDANCES

6 Year Avg	2008	2007	2006	2005	2004	2003	TYPE #	DEFINITION
132	400	0	306	11	4	68	1	Exceedance due to high runoff flows and flood control operations.
0	0	0	0	0	0	0	2	Exceedance due to intertie line outages.
8	1	1	45	0	0	0	3	Exceedance due to unit outages during repair or maintenance.
18	0	0	106	3	0	0	4	Exceedance due to BPA inability to handle load; water was spilled.
0	0	0	0	0	0	1	5	Exceedance due to a breakdown in communication. Teletype went out but no change occurred or Project operator interpreted teletype differently than what was intended.
63	64	93	69	32	16	106	6	Exceedance due to uncertainties when using best professional judgment to apply the spill guidance criteria (travel time; degassing; water temperature effects; spill patterns).
15	21	5	29	15	0	18	7	Exceedance due to high TDG levels coming from the Mid-Columbia River Projects (see Pasco FMS readings).
1	0	0	0	0	3	0	8	Exceedance due to high TDG levels coming from the Snake River projects (see Ice Harbor Dam FMS readings).
0	0	0	0	0	0	0	9	Exceedance due to a load rejection. The powerhouse was not working and the river flow was spilled.
4	11	0	1	1	6	7	10	Exceedance due to the FMS gage malfunctioning and registering very high TDG levels
2	1	0	0	0	0	9	11	Exceedance due to mechanical problems (gate was stuck open, passing debris etc.).
11	12	0	3	7	25	20	12	Exceedance due to sharp rise in water temperature (a 1.5^{o}F or greater change in a day).
8	5	0	3	0	7	33	13	Exceedance due to bulk spill pattern being used which generated more TDG than expected.
2	0	0	13	0	0	0	14	Exceedance due to non-functioning of flow deflectors at Bonneville.
265	**515**	**99**	**575**	**69**	**71**	**262**		**Averages**

5.2.5 Recurring High TDG Exceedances

Historically there are three FMS locations that are difficult to avoid TDG exceedances from voluntary and involuntary spill. As a result, these record high recurring TDG exceedances in most years. These three sites are Camas/Washougal, Ice Harbor forebay and Lower Monumental forebay. As the 2008 data in Table 5 indicates, these three sites continued to be high recurring exceedances sites. The three recurring high TDG exceedance FMS sites typically have high TDG exceedances as a result of high flows and unit outages. This year, the Bonneville tailwater gage, Cascades Island, was among the high TDG exceedance sites. This tends to happen only during high runoff years. Since the gage was installed in 2005, there are only four years of TDG exceedance data for the Cascades Island gage. As Table 5 indicates, the gage had high TDG exceedances during the two high runoff years.

A review of the 1999-2008 daily TDG exceedances summarized on Table 5 highlights that the Camas/Washougal, Cascades Island, Ice Harbor forebay and Lower Monumental forebay gages have a history of recurring daily TDG exceedances. From a historical perspective, these four gages have the highest ten-year average number of daily TDG exceedances and four years average for the Cascades Island gage. These historical trends persisted into 2008. As Table 5 indicates, the other gages' ten year average number of daily TDG exceedances is far less than these four gages'.

5.2.5.1 Camas/Washougal

Historically, the Camas/Washougal FMS typically records the highest number of daily TDG exceedance, as was the case in the 2008 spill season. As indicated in Table 5, Camas/Washougal had the most daily TDG exceedances during the 2008 spill season with 68 daily TDG exceedances; the most during the last ten years (1999 – 2008) with an average of 40 daily TDG exceedances per year. The Camas/Washougal FMS represents a theoretical forebay in the lowest reach of the Columbia River. Because the Camas FMS is located in a shallow open river reach, it is more influenced by conditions such as winds, barometric pressures, changes in daily solar radiation, and swings in water temperatures than other FMSs. Production of oxygen by aquatic plants is also believed to be involved in causing some diurnal variations in TDG. Consequently, these factors contributed to the difficulty in making spill adjustments at Bonneville to remain at or below the 115% daily TDG limit at Camas/Washougal. The daily TDG exceedances at this gage are usually classified as Type 6 exceedances: "uncertainties associated with applying the spill guidance criteria". In most years, the TDG exceedances were classified as a Type 6. But this year, the TDG exceedances at the Camas gage were classified primarily as Type 1, due to high runoff and flood control operations.

Type 6 exceedances are typical for Camas/Washougal FMS. Type 6 daily TDG exceedance percentages from 2003-2008 were: 2008, 24%; 2007, 100%; 2006, 24%; 2005, 94%; 2004, 50%; 2003, 82%.

5.2.5.2 Cascades Island

As indicated on Table 5, Cascades Island recorded the second most number of daily TDG exceedances during the 2008 spill season. This was the highest number of daily TDG exceedances during the last ten years with an average of 30 TDG exceedances. The Bonneville tailwater FMS only has a four-year history since it was installed in 2005. As a result, a clear trend has not yet been established. However, it appears that Cascades Island has high TDG exceedance only during high runoff years.

5.2.5.3 Ice Harbor Forebay

Historically, the Ice Harbor forebay FMS has had a high number of daily TDG exceedances. This trend continued in the 2008 spill season. As indicated on Table 5, the Ice Harbor forebay recorded the third highest number of daily TDG exceedance during the 2008 spill season (55). This was also the third most during the last ten years, an average of 28 daily TDG exceedances per year. Historically, the Ice Harbor forebay is among the top TDG exceedance FMS site locations. The frequency of exceedances of the 115% daily standard at the Ice Harbor FMS was similar to the Lower Monumental forebay FMS. This suggests that the high TDG water coming from Lower Monumental dam plays a role in increasing the difficulty in managing the Ice Harbor forebay's TDG exceedances. The cumulative impacts of spill operations on the Snake River also contribute to the higher TDG in the river as the water moves downstream.

5.2.5.4 Lower Monumental Forebay

Historically, the Lower Monumental forebay FMS has recorded a high number of TDG exceedances. This trend continued in the 2008 spill season. As indicated on Table 5, the Lower Monumental forebay FMS recorded the fourth most number of TDG exceedances (54). This was the fourth most during the last ten years with an average of 27 TDG exceedances per year.

5.3 TDG Exceedances – Washington Calculations

The following description of Washington's new TDG calculation method was taken from the April 2, 2008 memo from the WDOE to the Columbia and Snake River Dam operations managers. This describes the States' concept and rationale for calculating the 12 hour average.

Washington's previous 1997 TDG Water Quality Standards (WQS) for fish spill on the Snake and Columbia rivers required TDG measurements to be taken at least hourly and the 12 highest measurements averaged over the course of a day. A day was assumed to be a 24-hour period, although the start and end time were never clearly defined. The measurements are reported based on a calendar day, starting 12 am and ending at 12 am. The term "day" did not need to be defined because averaging any high TDG from midnight to midnight captured all high TDG readings. Often the high readings for tailraces would occur during the early hours after midnight and in the evening hours with a period of lower readings in between during the day. This is because fish spill often occurs more at night.

The revised 2006 Washington WQS required measuring the average of the 12 highest consecutive hours in any one day. At 120% TDG or less, aquatic organisms experience the most TDG harm from consecutive exposure, not intermittent exposure, throughout a 24-hour period. High TDG and corresponding spills tend to occur during consecutive blocks of time. Measuring midnight to midnight breaks up the consecutive period of nightly high TDG.

Beginning the 2008 season, the operators were directed to use the following method to average and report the 12 consecutive hourly high TDG reading in a day:

Method for calculating the 12-hour rolling average: Use a rolling average to measure 12 consecutive hours. The highest 12 hour average in 24 hours is reported on the calendar day (ending at midnight) of the final measurement.

- The first averaging period of each calendar day begins with the first hourly measurement at 1:00 am. This hour is averaged with the previous day's last 11 hourly measurements.

- Each subsequent hourly measure is averaged with the previous 11 hours until there are 24 averages for the day.
- From the 24 hour averages, the highest average is reported for the calendar day.
- Round the 12-hour average to nearest whole number.

Rationale for the rolling average: The standards state “in any one day”, but a day need not be a calendar day. Defining a day as starting at a set hour (like midnight) and ending 24 hours later leaves only twelve 12-hour blocks to average within 24 hours. If a period ends at midnight, night spill TDG measurements would be cut off during the middle of the night and the consecutive readings of the highest spill period would be averaged since the period from 12 midnight on would not be counted with the previous day. So a rolling 12 hour average makes the most sense. This method best captures consecutive hours of high TDG not only below dams that spill captures consecutive forebay reading which measure TDG from the upstream dam hours later.

5.3.1 115% and 120% TDG Exceedances

The revised Washington water quality standards require that the new method of calculating the average of the 12 highest consecutive hours begin in 2008. The Corps calculated the number of TDG exceedances for the 2008 spill season using this method. Table 8 shows the number of TDG exceedance for 2008 per to the new Washington method of calculating the high 12-hour average TDG. Table 8 also compares the new Washington method to the old method which is referred to as the Oregon method.

TABLE 8
2008 SPILL SEASON TDG EXCEEDANCES
COMPARISON OF WA AND OR METHODS

Water Quality Gages	WA - 2008 Qty.	OR - 2008 Qty.	Difference Qty.
Lower Granite Forebay *	0	0	0
Lower Granite Tailwater	37	35	2
Little Goose Forebay *	36	34	2
Little Goose Tailwater	22	23	-1
Lower Monumental Forebay *	57	54	3
Lower Monumental Tailwater	31	32	-1
Ice Harbor Forebay *	57	55	2
Ice Harbor Tailwater	32	31	1
McNary Forebay - WA *	25	21	4
McNary Forebay - OR	--	--	--
McNary Tailwater	30	28	2
John Day Forebay	17	14	3
John Day Tailwater	20	17	3
The Dalles Forebay	18	17	1
The Dalles Tailwater	3	2	1
Bonneville Forebay	34	27	7
Cascade Island	58	57	1
Warrendale	--	--	--
Camas/Washougal	84	68	16
Total Number of Exceedances	**561**	**515**	**46**
Tailwater Exceedances	**233**	**225**	**8**
Forebay Exceedances	**328**	**290**	**38**

5.3.2 Comparison of Washington and Oregon Calculation Methods

As Table 8 indicates, there were 561 TDG exceedances during 2008 spill season per the Washington method. This is 46 more TDG exceedances than the Oregon (515). The fact that the Washington method resulted in 46 additional TDG exceedances shows that it is more stringent. As Table 10 shows, these 46 additional TDG exceedances occurred primarily at project forebay gages, with the Camas Washougal gage having an additional 16 exceedances, the largest number of additional TDG exceedances for any gage. The additional TDG exceedances at the other forebay gages ranged from 1 to 7. Since the project forebay gages are typically a limiting factor for spill, it is reasonable to expect that a more stringent method of calculating the high 12 hour average would impact the forebay gages the most.

The tailwater gages were also impacted, but to a much less degree. The difference between the Washington and Oregon method of calculating TDG exceedances resulted in the tailwater gages TDG exceedances ranged from a loss of 1 to a gain of 3. These results suggest that the Washington method of calculating TDG exceedances are not always more stringent and that it can be less stringent at some tailwater gages. The two tailwater gages that indicated a loss of 1 TDG exceedance compared to the Oregon method was the Little Goose tailwater and Lower Monumental tailwater gages.

As Table 9 shows, if the Washington calculation method would be used, the largest maximum (increase) change in the calculation of high 12-hour TDG levels could ranged from 3.9 to 4.4% and would occurred at Little Goose tailwater, Camas/Washougal and Bonneville forebay FMS gages. As Table 9 indicates, the large minimum (decrease) change in the calculation of high 12 hour TDG levels ranged from 2.2% at the Dalles forebay and 3.7% at John Day tailwater gages.

TABLE 9
Maximum, Minimum and Average Difference
Between WA And OR TDG Calculation Methods in %

Gage Name	Maximum	Minimum	Average
Lower Granite forebay	1.2	-0.3	0.02
Lower Granite tailwater	2.2	-1	0.1
Little Goose forebay	2.5	-0.3	0.4
Little Goose tailwater	4.4	-0.8	0.4
Lower Monumental forebay	2.5	-0.3	0.3
Lower Monumental tailwater	3.1	-0.9	0.0
Ice Harbor forebay	2.7	-0.3	0.3
Ice Harbor tailwater	2.1	-1.2	0.1
McNary forebay	3	-0.4	0.3
McNary tailwater	1.6	-0.4	0.1
John Day forebay	2.7	-0.2	0.3
John Day tailwater	2.4	-3.7	0.1
The Dalles forebay	3.2	-2.2	0.4
The Dalles tailwater	2.8	-0.6	0.2
Bonneville forebay	3.9	-0.6	0.5
Cascade Island	2.4	-0.6	0.1
Camas Washougal	4	-0.4	0.6
Average	**2.7**	**-0.8**	**0.3**

TABLE 10
FOREBAY GAGES MOST EFFECTED
BY CHANGING CALCULATION METHODS

Water Quality Gages	WA - 2008 Qty.	OR - 2008 Qty.	Difference Qty.
Camas/Washougal	84	68	16
Bonneville Forebay	34	27	7
McNary Forebay	25	21	4
Lower Monumental Forebay	57	54	3
John Day Forebay	17	14	3
Little Goose Forebay	36	34	2
Ice Harbor Forebay	57	55	2
The Dalles Forebay	18	17	1
Lower Granite Forebay	0	0	0
Total Number of Exceedances	**328**	**290**	**38**

5.4 Water Temperature

This report contains three appendices that summarize water temperature data: Appendix H summarizes hourly water temperatures in the forebays and the tailwaters of the Corps projects. Appendix H Table H-1, which shows the number of days that 68°F is exceeded on a daily average for one hour or more. Appendix I contains graphs of Dworshak and Lower Granite tailwater temperatures with a summary of the Dworshak spill operations. Appendix E contains temperature graphs that were in the court reports.

The NOAA Fisheries 2004 BiOp calls for cold water releases from Dworshak reservoir. These releases are to reduce and/or maintain cooler water temperatures in the Snake River in the July through September time period when ambient conditions would typically cause the temperature to rise above 68°F. As discussed in Section 4.1.8 Dworshak Releases, the Corps achieved the objective of drafting Dworshak from 1600 feet elevation to 1520 feet between July and mid-September for water temperature reductions and flow augmentation on the Snake River. As discussed in Appendix I, the cold water releases produced the desired effect of reducing and maintaining cooler water temperatures on the Snake River.

5.4.1 State Water Quality Standards for Temperature

The water temperature standards for the Lower Columbia and Snake Rivers as defined by the states of Idaho, Oregon, and Washington are shown in Table 11 and 12.

TABLE 11
State Water Quality Standards
The Lower Snake Projects

Projects	**Washington Standard**	**Idaho Standard**
Lower Granite Dam, Snake River, RM 107.5 **AND** Little Goose Dam, Snake River, RM 70.3 **AND** Lower Monumental Dam, Snake River, RM 41.6 **AND** Ice Harbor Dam, Snake River, RM 9.7	"Temperature shall not exceed 20°C (68°F) due to human activities. When natural conditions exceed 20°C (68°F) no temperature increases will be allowed which will raise the receiving water temperature by greater than 0.3°C (0.5°F) nor shall such temperature increases, at any time exceed t=34/(T+9)." WAC 173-210A-130(98)(a)	Lower Snake – Asotin (Idaho/Oregon border) to Lower Granite Dam pool, Hydrologic Unit Code (HUC) 17060103, Rule Section 130.02. Aquatic Life: COLD (Cold Water Communities) "Water temperatures 22°C or less with a maximum daily average of no greater than 19°C"

TABLE 12
State Water Quality Standards
The Lower Columbia River Projects

Project	Washington Standard	Oregon Standard
McNary Dam. Columbia River, RM 292.0; **AND** John Day Dam, Columbia River, RM 215.6; **AND** Bonneville Dam, Columbia River, RM 146.1; **AND** The Dalles Dam, Columbia River, RM 191.5	"Temperature shall not exceed 20°C (68^{o}F) due to human activities. When natural conditions exceed 20°C (68^{o}F) no temperature increases will be allowed which will raise the receiving water temperature by greater than 0.3°C (0.5^{o}F) nor shall such temperature increases, at any time exceed 0.3^{o}C (0.5^{o}F) due to a single source or 1.1°C (2.0^{o}F) due to all such activities combined." WAC 173-210A-130(20)	From June 1 to September 30, "To accomplish the goals identified in OAR 340-041-0120(11), unless specifically allowed under a Department-approved surface water temperature management plan as required under OAR 340-41-026(3)(a)(D), no measurable (defined as 0.25°F) surface water temperature increase resulting from anthropogenic activities is allowed:… (ii)when surface water temperatures exceed 68°F (20.0°C)." (OAR 340-041-0205(2)(b)(A). From October 1 to May 31, , "To accomplish the goals identified in OAR 340-041-0120(11), unless specifically allowed under a Department-approved surface water temperature management plan as required under OAR 340-41-026(3)(a)(D), no measurable (defined as 0.25°F) surface water temperature increase resulting from anthropogenic activities is allowed:…(iii) In waters and periods of the year determined by the Department to support native salmonid spawning, egg incubation, and fry emergence from the egg and from the gravels in a basin which exceeds 55°F(12.8°C)…" (OAR 340-041-205(2)(b)(A).(v) In water determined by the Department to support or to be necessary to maintain the viability of the native Oregon bull trout, when surface water temperatures exceed 50.0°F (10.0°C);

<u>Colville Tribal Temperature Standard</u>:
The WQS for the Confederated Tribes of the Colville Reservation were promulgated by EPA at 40 CFR 131.135. These standards apply to the Columbia River from the northern boundary of the reservation downstream to Wells Dam. The Columbia River is designated as "Class I (Extraordinary)" from the Northern Border of the Reservation to Chief Joseph Dam and "Class II (Excellent)" from Chief Joseph Dam to Wells Dam. The designated uses most sensitive to temperature are "Fish and shellfish: Salmonid migration, rearing, spawning and harvesting: other fish migration, rearing, spawning and harvesting."

The use designations and corresponding temperature criteria for the Colville Tribe are as follows:

Class I (Extraordinary)—Fish and shellfish: Salmonid migration, rearing, spawning, and harvesting: Temperature shall not exceed 16°C due to human activities. Temperature increases shall not, at any time, exceed $t = 23/(T + 5)$. When natural conditions exceed 16°C, no temperature increase will be allowed that will raise the receiving water by greater than 0.3°C. For purposes hereof, "t" represents the permissive temperature change across the dilution zone; and "T" represents the highest existing temperature in this water classification outside of any dilution zone. Temperature increase resulting from nonpoint source activities shall not exceed 2.8°C and the maximum water temperature shall not exceed 16.3°C.

Class II (Excellent)—Fish and shellfish: Salmonid migration, rearing, spawning, and harvesting:

Temperature shall not exceed 18°C due to human activities. Temperature increases shall not, at any time, exceed $t = 28/(T + 7)$. When natural conditions exceed 18°C, no temperature increase will be allowed that will raise the receiving water by greater than 0.3°C. For purposes hereof, "t" represents the permissive temperature change across the dilution zone; and "T" represents the highest existing temperature in this water classification outside of any dilution zone. Temperature increase resulting from nonpoint source activities shall not exceed 2.8°C and the maximum water temperature shall not exceed 18.3°C.

Part 6 Fish Passage Summary

6.1 Biological Monitoring

The spill cap levels in the FOP, consistent with state and water quality waivers and criteria adjustments are: a daily average (based on the12 highest hours) of 115% in the project forebays, a daily average (based on the 12 highest hours) of 120% in the project tailwaters, and a maximum high 2-hour average of 125% anywhere in the river. The NOAA Fisheries 2004 BiOp and the state TDG waivers and criteria adjustments call for biological monitoring for GBT, which the Action Agencies performed in accordance with RPA action 131.

The monitoring of juvenile salmonids in 2008 for gas bubble trauma (GBT) was conducted at the mid Columbia, lower Columbia and Snake River sites. Fish were collected and examined for signs of GBT at Bonneville Dam and McNary Dam on the Lower Columbia River, and at Rock Island Dam on the Mid-Columbia River. The Snake River monitoring sites were Lower Monumental Dam, Little Goose Dam, and Lower Granite Dam. Prior to 2005, monitoring was conducted at all sites during the spring spill season and at mid Columbia and lower Columbia River sites during the summer spill program. However, beginning in 2005, summer monitoring at the Snake River sites started as a result of the Court ordered summer spill program. This year, summer spill in the Snake River occurred from June 20, 2008 until August 31, 2008.

Sampling occurred two days per week at the Columbia River sites and one day a week at each of the Snake River sites during the time period that spill was implemented. The goal was to sample 100 salmonids of the most prevalent species (limited to Chinook and steelhead) during each day of sampling at each site. The proportion of each species sampled was dependent upon their prevalence at the time of sampling. Examinations of fish were done using variable magnification (6x to 40x) dissecting scopes. The eyes and unpaired fins were examined for the presence of bubbles. The bubbles present in the fins were quantified using a ranking system based on the percent area of the fins covered with bubbles (see Table M-1 of Appendix M).

In all, 12,884 juvenile salmonids were examined for GBT between April and August of 2008 (Table M2 of Appendix M). Fin signs were found in 89, or 0.5%, of the fish sampled at all sites (see Table 3 of Appendix M). One fish was found with severe fin signs (rank 3 or higher) while, 5 and 83 fish had less severe fin signs of rank 2 and 1, respectively. Table

M4 of Appendix M compares the 2008 estimates of the overall percentage of fish with signs of GBT to past years' estimates.

The 2004 BiOp Spill Program was managed using the data collected for TDG levels. However, signs of GBT in fins of juvenile fish, examined as part of the biological monitoring, were used to complement the physical monitoring program. NOAA Fisheries originally established the action criteria for the biological monitoring program at 15% prevalence of total examined fish having fin signs or 5% with severe signs (rank 3 or greater) in fins. The criteria were never exceeded in the Snake or Columbia Rivers in 2008.

One reportable incident occurred at Little Goose Dam early in the season (April 15) when flows were low and TDG levels were well below criteria. The crew reported 25 out of 100 fish sampled exhibited signs of GBT. Upon review it was determined that the person examining the fish may have misidentified deformed fin rays as bubbles, particularly in steelhead dorsal fins. A total of 23 of 25 fish identified with GBT were steelhead. Only six steelhead had signs of GBT in other paired fins when the dorsal fin information was excluded. A total of two yearling Chinook in the sample were identified with GBT. Together this would have translated to 8% signs on that date for non-dorsal fins. These data were eliminated from the database because of the extenuating circumstances.

The site where the most fish were observed with signs of GBT in the FCRPS was at Lower Monumental Dam (Figure 3). The incidence of GBT reflects the operations upstream at the projects where considerable amounts of uncontrolled spill took place causing TDG levels to exceed 120%, and at times, as high as 130%, in the forebay of Lower Monumental Dam. The percentage of fish showing signs of GBT peaked in early June, but did not exceed the action criteria of 15%. As shown in Figure M-3, the highest levels of GBT observed occurred on June 9th with GBT levels of about 12%.