US Army Corps of Engineers®

Northwestern Division

2009 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 Team

December 2009

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Portland, Oregon

Including Material Provided by:
Portland District – U.S. Geological Survey (Portland Office)
Walla Walla District – U.S. Geological Survey (Pasco Office)
Seattle District – Columbia Basin Environmental.
Corps of Engineers' Engineering Research and Development Center
Fish Passage Center

2009 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	U.S. 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
Kaf	thousand acre feet
LCA	Libby Coordination Agreement
Maf	million acre-feet
MOP	minimum operating pool
NMFS	National Marine Fisheries Service (also, NOAA Fisheries)
NOAA Fisheries	National Oceanic and Atmospheric Administration, Fisheries
NWF	National Wildlife Federation
NWPPC	Northwest Power and Conservation 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 U.S. 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 2009 Water Management Plan.

Involuntary Spill: Spill that result 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 resulting in flows which exceed 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 be 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.

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 Federal agencies (Bonneville Power Administration (BPA), Bureau of Reclamation (BoR), NOAA Fisheries, Corps, USF&WS)), four states (Idaho, Montana, Oregon, and Washington), and participating Tribes.

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

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 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.

Part 1 Program Description

1.0 Introduction

This report describes the U.S. Army Corps of Engineers' (Corps') Columbia River Basin spill and water quality monitoring program for 2009 and covers the lower Columbia and Snake River projects. This report was developed to meet the Corps water quality program responsibilities related to the Clean Water Act; Oregon Total Dissolved Gas (TDG) variance and the Washington TDG rule adjustment; 2009 Fish Operations Plan and 2008 Biological Opinion.

The Clean Water Act information that this report provides includes status updates on meeting the TDG TMDL objectives. The Oregon TDG waiver and Washington rule adjustment information that this report provides includes weather, flow and runoff conditions for the spill season, spill quantities and durations, quantities of water spilled for fish 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 rule adjustments to the state Water Quality Standards (WQS) for TDG. This report includes documentation on the status of meeting the National Marine Fisheries Service 2008 Biological Opinion, Reasonable and Prudent Alternative (RPA) Actions 4, 15 and 32, which are associated with Dworshak operations; the Water Quality Plan for TDG and temperature on the mainstem Columbia and Snake rivers and the TDG monitoring program.

This report focuses on the spill and water quality monitoring of TDG and temperature at the 10 Corps dams in the Columbia River Basin (Bonneville, The Dalles, John Day, McNary, Chief Joseph, Ice Harbor, Lower Monumental, Little Goose, Lower Granite, and Dworshak dams).

This report also provides a detailed review of spill, 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 2009. The Fish Operations Plan (FOP) that was used as the guideline for 2009 spill season can be found as Appendix C. Appendix D reports on the Fish Operations Plan spill operations for 2009. Appendix E contains the 2009 monthly spill court reports filed with the court during spill season. This appendix contains graphs of flow, spill and high 12 hour percent TDG average along with variance tables. Appendix F provides summary tables of TDG levels and instances and instance types of when TDG levels exceed state WQS. Appendix G provides a detailed evaluation of how well SYSTDG performed during the 2009 spill season. Appendix H provides graphs of hourly water temperature data. The Dworshak summer 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, and the Warrendale and Camas/Washougal sites. Appendix L provides a review of the QA/QC for the TDG and temperature monitoring gages at Chief Joseph dam. 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 TMDL activities.

1.1 Clean Water Act and Endangered Species Act

1.1.1 General

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

1. Monitor spill in relation to the 2009 FOP spill objectives
2. Documents the status of Corps actions on 2008 BiOp water quality objectives.
3. Monitor project performance in relation to water quality standards,
4. Provide water quality data for anadromous fish passage at Columbia/Snake mainstem dams.

Voluntary spill is monitored at the Columbia River Basin projects of Grand Coulee; Chief Joseph; McNary; John Day; The Dalles; Bonneville; Ice Harbor, Lower Monumental, Little Goose, Lower Granite, and Dworshak. Project and monitoring data is reviewed daily as part of the process of setting daily spill caps to maintain TDG levels within the 115 and 120 % TDG criteria. Instances of the TDG and temperature criteria are tracked and actions are taken to meet the criteria.

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.

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).

1.1.2 Corps Goals

The Corps' policy is to comply with WQS 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 July 30, 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 of spill management and monitoring consistency with WQS.

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 rivers mainstem dams up to a level of 120% TDG where state rule adjustments, variances or waivers had been provided.

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 for the FCRPS, 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 2008 BiOp

The NOAA Fisheries 2008 Biological Opinion was finalized on May 5, 2008, however, prior to the start of the fish passage season the Court ordered project operations related to spill for fish passage, spill studies, and fish transportation to follow the 2008 Fish Operations Plan (FOP) and that implementation of all other operations outlined in the 2008

BiOp would begin September 1, 2008. For the 2009 fish migration season, the Court suggested and the Federal agencies agreed to adopt 2008 FOP operations. The Federal agencies produced the 2009 Spring FOP, followed by a 2009 Summer FOP. These Fish Operations Plans can be found as Appendix C.

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 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 TDG pressure relative to the water surface exceeding 110% of saturation.

State of Oregon:
The Oregon **OAR 340-041-0031** regulation on Total Dissolved Gas 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 TDG relative to atmospheric pressure at the point of sample collection may not exceed 110% of saturation. However, in hatchery-receiving waters and other waters of less than two feet in depth, the concentration of TDG relative to atmospheric pressure at the point of sample collection may not exceed 105% of saturation.

The Corps received a TDG waiver on June 22, 2007 from the State of Oregon for the 2008-2009 spill seasons. The Environmental Quality Commission approves a modification to the TDG standard for voluntary spill at McNary, John Day, The Dalles and Bonneville dams on the lower Columbia River, subject to the nine conditions. There are three conditions that are highlighted for the purposes of this report:

1. Spill must be reduced when the average TDG concentration of the 12 highest hourly measurements per calendar day exceeds 115% of saturation in the forebays of McNary, John Day, The Dalles, and Bonneville dams monitoring stations.

2. Spill must be reduced when the average TDG concentration of the 12 highest hourly measurements per calendar day exceeds 120% of saturation in the tailraces of McNary, John Day, The Dalles, and Bonneville dams monitoring stations.

3. Spill must be reduced when instantaneous TDG levels exceed 125% of saturation for any 2 hours during the 12 highest hourly measurements per calendar day.

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% of saturation at any point of sample collection for all designated Aquatic Life Uses. The rule found in WAC 173-201A-060 on TDG allows for adjusted TDG criteria when spilling water over dams to aid fish passage. The exemption requires that, when spilling water at dams is necessary to aid fish passage, TDG must not exceed an average of 115% 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 consecutive 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.

1.1.5 TDG Waiver History

The Corps receives a TDG waiver from Oregon and a TDG rule adjustment from Washington. The following sections provide the history of the waivers and rule adjustments from each state.

State of Oregon

The Corps took appropriate actions for attaining a TDG variance from the State of Oregon for the 2002-2009 spill seasons. NOAA Fisheries submitted the first federal request for a TDG waiver from the Oregon Department of Environmental Quality (ODEQ) in 1995. NOAA Fisheries continued to apply and obtained the TDG waiver each year from 1995 to 2000. When the 2000 Biological Opinion was passed, NOAA Fisheries decided that it was more appropriate for the Corps to apply for the waivers. The first request from the Corps was in 2002, and included the 2001 TDG and temperature report with a request for a TDG variance for the 2002 spill season. The Oregon Environmental Quality Commission approved a variance for the 2002 spill season. Based on this approval, the ODEQ issued a TDG waiver, subject to specific conditions listed below.

On December 23, 2002, the Corps submitted information for a multi-year TDG variance to the ODEQ. The Oregon Environmental Quality Commission met on March 11, 2003 and approved a 5-year TDG waiver subject to the same restrictions and conditions as the previous variance. This new waiver was in effect for 2003 through 2007 spill seasons.

On November 30, 2006, the Corps submitted a package of information to ODEQ for its use in processing a multi-year variance to the Oregon TDG standard for the period 2008 through 2012 with the same conditions as specified in the previous variance. The Oregon

Environmental Quality Commission met on June 21, 2007 and approved a 2-year variance for the 2008-2009 spill seasons.

State of Washington:

In its 1997 WQS, 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)), is subject to approval of a gas abatement plan, and submission of a fisheries management plan, and plans for physical and biological monitoring. NOAA Fisheries submitted the first federal request for a TDG rule adjustment from Washington DOE in 1995. NOAA Fisheries continued to apply and obtained the rule adjustments each year from 1995 through 2000. When the 2000 Biological Opinion was issued, NOAA Fisheries decided that it was more appropriate for the Corps to apply for the state TDG rule adjustments. The first request from the Corps was in 2002, and included a gas abatement plan which was approved by Washington DOE for the 2002 spill season.

In December 2002, the Corps submitted a package to the Washington Department of Ecology (WDOE) to satisfy the requirements for a TDG rule adjustment. In a letter to the Corps, dated March 28, 2003, the WDOE approved the updated gas abatement plan for all activities related to fish passage which results in a TDG rule adjustment that covered the 2003 spill season. In December 2003, the Corps submitted another package to the WDOE which contained a Water Quality Plan which was greatly expanded and covered a period extending through 2015. In response to this submittal, the WDOE approved the gas abatement plan which resulted in a TDG rule adjustment that covered the 2004 spill season. On January 14, 2005, the Corps submitted another package of documents intended to satisfy the State of Washington's requirement for a 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 issued a rule adjustment that covered 2005 – 2007 spill seasons.

On November 30, 2006, the Corps submitted another package of documents intended to satisfy the State of Washington's requirement for a TDG rule adjustment, which included the annual TDG and Temperature report and an updated the gas abatement plan. Based on this submittal and additional coordination with the Corps and ODEQ, the WDOE issued a rule adjustment to the Corps covering 2008 and 2009 spill seasons.

Colville Tribe TDG Standards:

4-8-5(e): The Water Quality Standards herein established for the TDG 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 110% of saturation at any point of sample collection.

1.1.6 TDG TMDL Progress

One of the conditions of the Oregon TDG waiver and the Washington rule adjustment is to provide 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. This table includes some actions that are being implemented in the hydrosystem but were not on the original TDG TMDL list. 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 Team 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, spill levels and, potentially, spill patterns at the dams are monitored and changed (daily, if necessary) so that TDG levels are consistent with the applicable state standards (including waivers or rule adjustments); For the 2009 spill season, forebay TDG levels are not to exceed, daily (12 highest hours) average of 115% TDG, and the tailwater levels are not to exceed, daily (12 highest hours) average of 120% TDG. The use of the TDG standard and forebay gages is consistent with the U.S. District Court of Oregon orders. When adjustments to spill caps 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 2009 Water Year (WY), which began in October 2008, was average in precipitation. The accumulative precipitation during WY 2009 in the upper Columbia River Basin was 88% of normal (1971-2000) above Grand Coulee Dam, 109% of normal in the Snake River above Ice Harbor Dam, and 97% 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.

October 2008 transitioned from the high pressure weather pattern of the summer and autumn to an early glimpse of winter, as a progressive set of weather systems moved through the Columbia Basin. There was one significant, and unseasonably cool, storm that brought early season snow to the region. This weather system helped many locations break daily low temperature records. The Basin temperature profile, from the 31-station index, could not have been closer to normal, at 0 °C (-0.1 °F), as milder British Columbia temperatures offset those in the U.S. part of the Basin. Precipitation-wise, Pocatello broke a daily snowfall record of 8.1 cm (3.2 inches) on the 12. October precipitation was 82% of normal for Columbia above Coulee, 76% of normal at the Snake River at Ice Harbor, and 78% of normal at Columbia above The Dalles.

By November, the progression of weather systems adjusted toward the close of month, so that the onus of the precipitation fell across Washington through central Idaho, leaving both the Canadian, and remaining U.S. districts, drier than normal. With the heavy rainfall across Washington, then, numerous rivers in western Washington exceeded flood stage during an early month precipitation event. This was a mild airflow, and regional temperatures were warmer than normal, especially closest to the Continental Divide. Precipitation was 91% of normal at Columbia above Coulee, 111% of normal at the Snake River at Ice Harbor, and 103% of normal at Columbia above The Dalles. The weather pattern again adjusted by late November into early December, and transitioned into what many experts believed to be a "classic La Niña" for the Pacific Northwest and western Canada.

December averaged drier than normal, the look of La Niña brought a strong low pressure area into the region. This stormy, and increasingly cold, regime held through Christmas. The month had numerous record cold temperatures along with record valley snowfall amounts. At the end of the month, a few warm fronts added more, much-needed, precipitation to the region. The month ended up colder than normal, as the Columbia Basin registered temperatures -1.1 °C (-2 °F). The record snow fall amounts included 43.2 cm (17 inches) at the Spokane International Airport on the 17, while Coeur d'Alene recorded 63.5 cm (25 inches). With snowfall, and late month warm frontal valley rainfall, the contribution resulted in precipitation averaging 103% of normal at Columbia above Coulee, 138% of normal at the Snake above Ice Harbor, and 108% of normal at Columbia above The Dalles.

January opened up with two strong storm systems bringing heavy precipitation and a turn from colder, to warmer than normal, temperatures to the region for the first two weeks of the New Year. First, temperatures responded, recoiling from the chill of December, such that January saw a few record high temperatures. Even with the rain and snow during the month, there were only a few precipitation records. Flooding again occurred in western Washington, including along the Interstate between Seattle and Portland in the vicinity of the Chehalis River. Some flooding, from rain on snow due to warming temperatures, occurred in northern Idaho. In both cases, the flooding was complicated by ice jam releases. Drier conditions developed later in the month, as the jet stream moved north into B.C. Yet, January precipitation was 109% of normal at Columbia above Coulee, 104% of

normal at the Snake River above Ice Harbor, and 109% of normal at Columbia above The Dalles.

For the start of February, high pressure aloft covered the U.S. part of the Columbia Basin because of the jet stream over Canada,. This brought deceptively quiet and mild weather to areas east of the Cascades. It also brought some record warmth to the coast. Much colder temperatures returned to the region the last half of the month. The regional temperatures departed -0.3 °C (-0.6 °F)) from normal, as gauged by 37 stations across the Basin. As the month opened up drier than normal, it ran its course to wetter than normal during the last week. A strong, wet and initially warm weather system brought record daily rainfall to some areas of the region, followed by an equally cold and wet system that brought record daily snowfall. February precipitation was 65% of normal at Columbia above Coulee, 56% of normal at the Snake River above Ice Harbor, and 58% of normal at Columbia above The Dalles. The colder temperatures of the last part of February dovetailed into colder than normal readings for March.

For March a series of strong low pressure systems kept much cooler than normal conditions in the Basin, as well as delivering moderate to heavy precipitation, especially during the first half of the month. There was a break about mid-month, then a resumption of storminess late month. With very chilly air overhead for almost the whole month, the region had numerous record low temperatures, mainly east of the Cascades. The low pressure systems of the month contributed to record daily precipitation. All this brought March precipitation totals to 127% of normal at Columbia above Coulee, 128% of normal at the Snake River above Ice Harbor, and 130% of normal at Columbia above The Dalles. Another break in the weather occurred at the close of March, and led to a quiet first week, of April.

In April, the La Niña conditions in the equatorial Pacific continued to govern the mid latitude weather pattern. This produced a swing of weather conditions from initially cold and wet, to warmer and drier, and back to wet and cold, quite typical of La Niña Springs. Most prominent during the month, was the warm weather about mid-month. This was courtesy of a high pressure system. So, from March's extreme chill to April's warmth, we set new records on both counts. For the Basin, April sat at -0.5 °C (-0.9 °F) departure from normal, with the warmest departure range at 1.1 °C (2 °F), according to the 37 station index. Compared to March, and more like February, April was drier than normal. April precipitation was 61% of normal at Columbia above Coulee, 100% of normal at the Snake River above Ice Harbor, and 86% of normal at Columbia above The Dalles. The low pressure of latter part of April carried through into May.

The low helped May start out cool and wet, and by mid-month high pressure brought dry and warm weather to the region. The summer-time regime of monsoon moisture from the Southwest U.S., started up later in the month, and this brought back rainfall, as showers and thundershowers. Again, with the back-and-forth rhythm of a La Niña Spring, temperatures went from cool, early on, to quite warm, then back to cool. Regional temperature departures ranged from -0.7 to 3.1 °C (-1.2 °F to 5.5 °F), and this ironed out to 0.8 °C (+1.4 °F) from normal, an overall mild month. While the bulk of the precipitation

that fell in May came from the low pressure early in the month, daily record amounts came from the monsoonal precipitation. May precipitation was 82% of normal at Columbia above Coulee, 91% of normal at the Snake River above Ice Harbor, and 91% of normal at Columbia above The Dalles. Month-end cool weather continued into June 2009.

In June the Columbia Basin saw mainly above normal precipitation, largely over the U.S. districts east of the Cascades. A semi-permanent low pressure area near the Four Corners region supplied the southern Columbia Basin will plenty of showers and thundershowers. These brought precipitation totals above normal, and produced record rainfall. In the north, the Canadian districts had a weak weather system impact them with lighter precipitation, and temperatures nearer to normal. The 37 station temperature index for the region departed 0.1 °C (+0.2 °F). In all, June precipitation was 69% of normal at Columbia above Coulee, 242% of normal at the Snake River above Ice Harbor, and 127% of normal at Columbia above The Dalles. As is often the case, a cool June in the U.S. part of the Basin, quickly turned warm in July of this year.

July started out with another low pressure trough, but by mid-month a definitive regime change brought strong high pressure into the Basin. All-time high temperatures were reported in parts of the Pacific Northwest as a result, yet they quickly followed a run of record cool readings. Rainfall records came with the cooler air-mass of early July. July precipitation was 106% of normal at Columbia above Coulee, 58% of normal at the Snake River above Ice Harbor, and 85% of normal at Columbia above The Dalles.

During the first two weeks of August the coastal region saw fairly nice seasonal weather while the eastern northwest was hit with a few strong weather systems. These systems brought thunderstorms and above normal precipitation to the northern Rockies. By the third week of August high pressure brought warm dry weather to most of the region. Warm dry weather continued through the west through the end of the month while showers and thunderstorms returned to the Northern Rockies the last week of August. The 37 station temperature index for the Pacific Northwest departed +0.7 degrees from normal. Overall, precipitation was 103% of normal at the Columbia River above Grand Coulee, 151% of normal at the Snake River above Ice Harbor, and 119% of normal at the Columbia River above The Dalles.

In September a strong cold frontal system brought heavy precipitation and cool temperatures to the Pacific Northwest the end of the first week of September. High pressure built over the region behind this system to bring warm and dry conditions through the second week. High pressure dominated the weather over the Columbia Basin through the third and beginning of the fourth week, bringing warm and mainly dry conditions. The 37 station temperature index for the region departed 0.7 ° from normal. Precipitation was 51% of normal at the Columbia River above Grand Coulee, 25% of normal at the Snake River above Ice Harbor, and 47% of normal at the Columbia River above The Dalles.

2.1.2 Streamflow

The April 1, 2009 forecast of January through July runoff for the Columbia River above The Dalles was 113.5 km^3 (92.0 million acre feet (MAF)) and the actual observed runoff was 111.3 km^3 (90.2 Maf). The average January-July runoff volume for the 1971-2000 period is 132.4 km^3 (107.3 Maf).

The August 2008 – July 2009 daily average unregulated stream flow in the Basin above The Dalles was below normal and approximately 4.2% lower than last year's average flow, which was also below normal. 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 June 2009; 90% of average at The Dalles.

The August 2008 through July 2009 runoff for The Dalles was 145.2 km^3 (117.7 Maf), which is 85% of the 1971-2000 average. The peak-unregulated discharge for the Columbia River at The Dalles was 16,210 m^3/s (572.5 kcfs) on June 8, 2009. The 2008-2009 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. These flows have been adjusted to exclude the effects of regulation provided by storage reservoirs.

TABLE 1
Columbia River Flow in 2008-2009

	At Grand Coulee (in cfs)		At The Dalles (in cfs)	
Time Period	**Unregulated flow**	**% of Average**	**Unregulated flow**	**% of Average**
October 2008	42,677	98	75,356	91
November 2008	49,862	78	97,339	103
December 2008	31,671	88	69,910	71
January 2009	38,857	73	102,588	100
February 2009	29,520	64	74,088	61
March 2009	42,222	62	104,263	67
April 2009	96,936	47	211,697	89
May 2009	210,444	117	389,267	90
June 2009	262,903	107	424,721	90
July 2009	142,323	97	188,268	73
August 2009	82,584	93	120,007	87
September 2009	51,077	84	80,471	86
Operating Year Average (Oct 08 – Sep 09)	**91,722**	82	**162,552**	**85**

2.1.3Reservoir Operation

2.1.3.1 General

The 2008 – 2009 operating year began with Grand Coulee storage at 92.2% full. The water year was below average for water supply across the basin, and the shape of the runoff included one modest peak starting the later half of May and continuing through the middle of June. The 2008-09 operating year began with Canadian storage at 91.8% full.

For 2008–09 operating year, water supply in the Columbia River above Grand Coulee was below average but about average for the Snake River at Lower Granite. The actual runoff for the overall Columbia basin (U.S. and Canada combined) measured at The Dalles for the January through July 2009 was 84% of normal.

The operations included refilling reservoirs to the April 10 flood control elevation, and if inflow were sufficient: 1) refill on, or about June 30, and; 2) drafting reservoirs to summer draft limits. The spring flow objectives were met at McNary and Lower Granite but not at Priest Rapids. Spring and summer spill 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 2009 water supply forecasts were 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. Inflow forecasts and reservoir regulation modeling were done weekly throughout the winter and spring. Projects were operated according to the May 2003 Flood Control Operating Plan (FCOP). The unregulated peak flow (based on the Corps SSARR program output) at The Dalles, Oregon, was estimated at 16,210 m^3/s (572.5 kcfs) on June 8, 2009, and a regulated peak flow of 9,894 m^3/s (349.4 kcfs) occurred on May 29, 2009 as measured at the United States Geological Survey gage at The Dalles, Oregon. The unregulated Corps peak stage at Vancouver, Washington, was calculated to be 6.30 m (20.7 ft) on June 8, 2009, and the highest observed stage was 3.33 m (10.9 ft) on June 9, 2009.

2.1.3.3 Total River Flows

Daily average total river flows on the lower Columbia River from April 10 through August 31 ranged from 93 kcfs to 360 kcfs, with a seasonal average of 218 kcfs. The daily average total river flow as measured at Bonneville dam remained below 300 kcfs until May 21 when the freshet began. Daily average flow remained above 300 kcfs from May 21 through June 11, with a peak of 360 kcfs on June10. It was during this period that involuntary spill occurred at one or more lower Columbia River projects. Flows began to taper off in late June and early July, dropping below 200 kcfs on July 13. Total river flows continued to recede on the Columbia River the rest of July and tapered off in August, until total river flows reached 93 kcfs on August 17. The overall daily average total river flows on the Columbia River during July was 165 kcfs, which is the lowest of the last five years. July river flows on the lower Columbia were 212 kcfs in 2008, 174 kcfs in 2007 and 184

kcfs in 2006 and 181 kcfs in 2005. Total river flows on the Columbia River during August were average at 118 kcfs, which is the lowest of the last five years. August river flows on the lower Columbia were 135 kcfs in 2008, 145 kcfs in 2007 and 141 kcfs in 2006 and 140 kcfs in 2005. It is significant that the July and August flows were lower than even 2007, which was considered a low water year.

On the lower Snake River, total river daily average flow remained between 137 to 169 kcfs between May 19 and June 9 with a seasonal average of 81 kcfs. The daily average total river flow as measured at Ice Harbor dam remained below 150 kcfs until May 21 when the freshet began. Daily average flow rose above 150 kcfs from May 21 through June 9, with a peak of 171 kcfs on June 8. It was during this period that involuntary spill occurred at one or more lower Columbia River projects and continued some after flows dropped below 150 kcfs. Flows began to taper off by mid June, dropping below 100 kcfs on June 25. Total river flows continued to recede on the lower Snake River the rest of July and in August, until total river flows reached 25 kcfs on August 26. The overall daily average total river flows on the lower Snake River during July was 51 kcfs, which is among the highest of the last five years. July river flows on the lower Snake were 57 kcfs in 2008, 31 kcfs in 2007 and 41 kcfs in 2006 and 37 kcfs in 2005. Total river flows on the lower Snake River during August were average at 32 kcfs, which is among the highest of the last five years. August river flows on the lower Snake River were 36 kcfs in 2008, 23 kcfs in 2007 and 27 kcfs in 2006 and 25 kcfs in 2005.

The typical criterion for expressing the water quality standards exemption is called the 7Q10. The 7Q10 is the average peak annual flow for seven consecutive days that has a recurrence interval of ten years. Washington and Oregon's water quality standards exempt these occurrences, since they are of natural origin and occur relatively infrequently. The 7Q10 daily average flows for the various projects are shown on Table 2. During very large natural runoff events, the resulting high river flows and involuntary spill at the projects make it impossible for dam operators to keep TDG levels below State criteria. When flows exceed the 7Q10 (the average peak annual flow for seven consecutive days that has a recurrence interval of ten years), Oregon and Washington's TDG criteria do not apply.

The 7Q10 flow levels were calculated based on the flow that projects can physically handle with all turbines except one operating. The 7Q10 flows were established through coordination with Oregon and Washington.

TABLE 2
7Q10 FLOWS

Project	7Q10 flows (kcfs)	Power house capacity (kcfs) within 1% efficiency	Power house capacity (kcfs) without one unit	The rate of spill at 7Q10 flows +
BON	467	257	242	225
TDA	461	288	267	194
JDA	454	331	310	144
MCN	447	172	160	287
IHR	214	92	77	137
LMN	214	115	94	120
LGS	214	115	94	120
LWG	214	115	94	120

+ Assuming no generation limitation due to lack of load.

The 2009 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 June 1 through June 21 in 1997. Flows at the Columbia River at Bonneville also exceeded the 7Q10 flow in 1974. 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 eight projects on the lower Columbia and Snake rivers. During the peak runoff period, involuntary spill occurred at the lower Columbia and Snake rivers projects.

2.1.3.4 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 saturations 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*, 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 (no flow deflectors) at Chief Joseph Dam. The evaluation of water quality benefits were based on reducing TDG saturation above and below Chief Joseph Dam while maintaining a constant joint power output from both projects. The study concluded that when Lake Roosevelt is below 1260 ft elevation, joint operations is recommended and spill from the outlet tubes at Grand Coulee should be shifted to spill at Chief Joseph Dam. At lake elevations above 1260 ft, spill over the drum gates at Grand Coulee is acceptable and no shift to Chief Joseph is

recommended. This joint operation of Grand Coulee and Chief Joseph will 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.

Flow deflector construction at Chief Joseph Dam was completed in October 2008. A TDG exchange study was conducted at Chief Joseph Dam from April 28 to May 2, 2009 to determine TDG exchange properties during spillway discharges with flow deflectors. Data from this study will be evaluated and used to develop an updated joint operations policy for Chief Joseph and Grand Coulee Dams based on the new TDG exchange properties at Chief Joseph Dam with deflectors. The updated joint operations policy is expected to be completed prior to the 2010 spill season. Joint operations with Grand Coulee were not conducted in 2009 due to no spill occurring at Grand Coulee Dam when the elevation of Lake Roosevelt was below 1260 ft.

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 eight FMSs on the lower Columbia River from John Day Dam to Camas-Washougal. The Seattle District is responsible for five 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 2009 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 2009 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

There are no noteworthy changes to the Corps TDG FMS system during 2009.

3.4 Malfunctioning Gage Occurrences

During 2009 there were eight occurrences where a FMS station gage malfunctioned due to various reasons. As a result, the data from these FMS gages showed elevated TDG levels ranging from approximately 118.7% to 151.6%. The gage data collected when a gage was malfunctioning is included in Tables F-2 and F-3 in appendix F to show when a TDG instance from a malfunctioning gage occurred and appeared as part of the real time operational review. Malfunctioning gage TDG instances are included as instance type 2a. Table F-2 indicates that there were 17 days where the high 12-hour average exceeded 120% due to instance type 2a. Table F-2 in appendix F is based on raw data and is populated during real-time operations. Tables F-4, F-5 and F-6 in appendix F do not include the malfunctioning gage data since these tables provide statistical information on hourly TDG levels and the Corps chooses to use only data with a high level of confidence.

3.5 QA/QC on FMS stations

The NMFS 2008 BiOp RPA Action 15 calls for "real-time monitoring and reporting of TDG and temperatures measured at fixed monitoring sites". Therefore, the Data Quality Criteria (DQC) for FMSs in the Pacific Northwest that was developed to meet the 2000 BiOp continue to be implemented today. This report provides the annual performance reports as required.

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 2009, an average of 99.2% of the TDG data were received in real-time by the USGS satellite downlink and 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.
- Data received from the individual sites ranged from 97.0% 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 4 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 but 2 of the 73 in-situ field checks of total-dissolved-gas sensors with a secondary standard were within ±1.0% saturation after 3 to 4 weeks of deployment in the river. All of the field checks of barometric pressure were within

±2.0 millimeter of mercury of a secondary standard, and water-temperature field checks were all within ±0.2°C.

- The eight fixed-station monitors were calibrated every 3 weeks, except from October 2008 through March 2009, when they were calibrated at 4-week intervals.
- All of the field checks of barometric pressure were within ±2.0 millimeter of mercury of a secondary standard, and water-temperature field checks were all within ±0.2°C.

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:

- Operated fifteen fixed-monitoring system (FMS) stations (nine seasonal and six year-round) for TDG, barometric pressure (BP), and temperature as part of their 2009 water-quality program. See Table J-7 in Appendix J for individual station data completeness information. These results exceed the DQC for data completeness. Table J-9 in Appendix J provides the causes for missing data.

- 99.77, 98.99, and 99.79% of the BP, TDG, and water temperature data, respectively, were received in real-time and passed provisional QA/QC review. Percent completeness subsequently increased to 99.94, 99.30, and 99.94% for BP, TDG, and temperature, respectively, after the data was compared to the information from the electronic data logger (EDL).

- 37.7% of the invalid/missing provisional real-time BP+TDG data was due to membrane failure followed by 20.3 and 18.2% attributable to DCP and communication cable failure, respectively. When the data was corrected with information from the EDL, 51.8% of the aberrant data was due to defective membranes while 29.7% was attributed to communication cable failure.

- The sonde pre-deployment check had calculated median TDG and temperature differences of -0.20 mmHg and 0.00 °C, respectively.

- All 15 FMSs are calibrated at three week intervals during the fish-spill season April 1 and August 31. The six year-round stations were calibrated at four week intervals between September 2008 and March 2009.

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 dam. The gage QA/QC work is performed through a contract with the Columbia Basin Environment.

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

- For the two monitoring sites associated with Chief Joseph dam in water year 2009, an average of 98% of the TDG data were received in real-time from the DCP by a radio transmitter. See Table 2 in Appendix L for individual gage data completeness information. These results do meet the DQC for data completeness.

- Missing data for all stations in 2009 were largely due to DCP malfunctions and programming problems. In general, these problems occurred during the first 2 weeks of April and were resolved by mid April. No data was rejected at station CHJ and CHQW.

- Laboratory calibration data were good and within 0.1^{o}C for temperature and 1% saturation 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.

- Total dissolved gas saturations at Chief Joseph forebay station (CHJ) exceeded 110% from about the beginning of June to the beginning of August 2009. Forebay TDG concentrations exceeded 115% in early July with a maximum concentration of about 117% measured on July 5, 2009. Except for the spill test conducted from April 28 to May 1, 2009, the Chief Joseph tailwater station (CHQW) exceeded 110% TDG saturation from about the beginning of June to the beginning of August, 2009. The tailwater station exceeded 120% only during a 100,000 cfs spill on June 6, 2009.

- Water temperatures at the Chief Joseph Dam forebay (CHJ) and tailwater (CHQW) were greater than 16°C and 18°C from about mid July through September and mid August through September, respectively.

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 instances of TDG levels exceeding the state TDG water quality standards. The Corps, in accordance with the 2008 NOAA Fisheries BiOp and the Corps' 2009 Fish Operations Plan, provides voluntary spill 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, transmission constraints, or unit outages, water is released through the spillway resulting in increased TDG levels.

The NOAA Fisheries 2008 BiOp and FOP voluntary spill for fish program was implemented consistent with the applicable state WQS waiver and rule adjustment. During spill 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%.

4.1.1 Fish Operations Plan

The fish operations that were implemented in 2009 are summarized on Table 3

TABLE 3
2009 FOP SPILL OPERATIONS

Project	Planning Dates	Time	Amount [c]	Minimum Generation Requirements kcfs
Lower Granite	April 3 - June 20	24 hours per day	20 kcfs (RSW with training)	11.3 - 13.1 [a]
Lower Granite	June 21 - August 31	24 hours per day	18 kcfs (RSW with training)	11.3 - 13.1 [a]
Little Goose	April 3 - August 31	24 hours per day	To the spill cap up to 30% of project outflow (RSW test being)	11.3 - 13.1 [a]
Lower Monumental	April 3 - June 20	24 hours per day	To the spill cap (~27 kcfs) - RSW test from April 27th - Early June	11.3 - 13.1 [a]
Lower Monumental	June 21 - August 31	24 hours per day	To the spill cap up to 17 kcfs	11.3 - 13.1 [a]
Ice Harbor	April 3 - April 28; July 12 - August 31	500 - 1800	45 kcfs	8.5 - 10.3 [a]
Ice Harbor	April 3 - April 28; July 12 - August 31	1800 - 500	To the spill cap	8.5 - 10.3 [a]
Ice Harbor	April 29 - July 11	24 hours per day	Test conditions of spill alternating between to the spill cap up to 30% of project outflow and 45kcfs daytime/spill cap at night [b]	8.5 - 10.3 [a]
McNary	April 10 - June 19	24 hours per day	To the spill cap up to 40% of project flow	50 - 60
McNary	June 20 - August 31	24 hours per day	To the spill cap up to 50% of project flow	50 - 60
John Day	April 10 - April 27; June 4 - August 31	24 hours per day	To the spill cap up to 30% of project outflow	50 - 60
John Day	April 27 to June 4	24 hours per day	Test days with spill of either 30% or approximately 40% of project outflow	50 - 60
John Day	April 10 - August 31	24 hours per day	Minimum spill is 25% of project outflow	50 - 60
The Dalles	April 10 - August 31	24 hours per day	To the spill cap or 40% of project outflow	50 - 60
Bonneville	April 10 - June 20	24 hours per day	To the spill cap up to 100 kcfs	30 - 40
Bonneville	June 21 - July 20	daytime [d]	To the spill cap up to 85kcfs	30 - 40
Bonneville	July 21 - August 31	daytime [d]	To the spill cap up to 75kcfs	30 - 40
Bonneville	June 21 - August 31	nighttime [d]	To the spill cap (~120 kcfs)	30 - 40
Bonneville	April 10 - August 31	24 hours per day	minimum spill is 75 kcfs	30 - 40

a - Minimum generation requirements at the Lower Snake River projects depend on the status of generation at other projects as well as the status of the transmission system and may not be needed all the time. Specific details of the minimum generation requirement is provided in the 2008 Water Management Plan and the 2008 Fish Operations Plan.

b - There is a fish test occurring at this project. See Fish test section

c - Spill cap is defined as the maximum spill amount that will keep the High 12 hr %TDG average within the State WQ standards of 115% in the forebay or 120% in the tailwater

d - Day and nighttime for Bonneville vary during the spill season and are set in the Fish Passage Plan.

4.1.4 Spring Creek Hatchery Spill

In 2008, the Corps, the Bonneville Power Administration, the National Marine Fisheries Service and the U.S. Fish and Wildlife Service entered into a Memorandum of Agreement (MOA) regarding Spring Creek National Fish Hatchery (SCNFH) fish production reprogramming. Under the MOA, a portion of the annual production was moved to the Bonneville Hatchery below Bonneville Dam, thereby eliminating the need to release fish in March and resultant requests for spill at Bonneville Dam. As a result, there were no spill operations in March 2009 for SCNFH fish releases. This agreement covers 2009 through 2011.

4.1.5 Fish Test Operations

During 2009, there were five fish test operations that affected spill for fish passage and 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. Little Goose Juvenile Passage and Survival Test
2. Lower Monumental Spillway Weir Test
3. Ice Harbor Fish Passage and Survival Test
4. McNary Spillway Weir Test
5. John Day Spillway Weir Test

Little Goose Juvenile Passage and Survival Test

Juvenile passage and survival was tested throughout the spill period. The spill operation was 30% of project discharge 24 hours/day. On August 18, the project began a flat spill of 11.6 kcfs for 24 hours/day through August 26, at which time the flat spill changed to 9.9 kcfs and continued through August 31, 2009. This change in operation was due to low flows and the inability to meet the spill requirements.

The objectives of the test were: (1) Determine the timing and route of passage for yearling Chinook salmon, and juvenile steelhead relative to spillway weir spill and powerhouse operations; (2) Estimate route-specific and overall concrete survival of hatchery yearling Chinook and hatchery steelhead; (3) Determine the effects of spillway weir operation and associated training spill, as well as powerhouse operations, on smolt approach paths in the forebay; (4) Determine direct survival and injury rates of fish passing through the spillway weir and spill bay 8, and; (5) Estimate survival (concrete) as the first year to determine if BiOp performance standards were being met with the tested configuration and operation.

The test resulted in spill levels ranging from 22 to 165 kcfs, which produced TDG levels fluctuating between 101.0 and 120.1% as shown on the weekly graphs in Appendix E. To find the Little Goose graphs, see the April report, Figures 2, 6, 14, 22 and 30. The weekly graphs for May, June and July at Little Goose are Figure 2, 10, 18 and 26 of the monthly reports. The weekly graphs for July at Little Goose are Figure 2, 10, 18, 26 and 34 of the monthly reports. The weekly graphs for August at Little Goose are Figure 2, 10, 18, 26 and 34 of the August reports.

Lower Monumental Spillway Weir Test
A two treatment spring spill test to evaluate juvenile fish passage and survival began on April 28 and concluded at 0500 on June 3. The test included alternating the spill pattern between a bulk and uniform patterns. The objectives of the test were to assess passage distribution and efficiency metrics, forebay retention, tailrace egress, vertical distribution of run-at-large fish passing over the spillway weir (SW), and survival for yearling Chinook and steelhead for two spill pattern treatments, a bulk spill pattern and a uniform pattern in conjunction with SW operation. This will be the second year of testing the SW at Lower Monumental Dam. An additional objective will be to estimate survival (concrete) to determine if BiOp performance standards are being met with the tested configuration and operation.

The test resulted in spill levels ranging from 19 to 177 kcfs, which produced TDG levels fluctuating between 101.8 and 123.1% as shown on the weekly graphs in Appendix E. To find the Lower Monumental graphs, see the April report, Figures 3, 7, 15, 23 and 31. The weekly graphs for May, June and July at Lower Monumental are Figure 3, 11, 19, 27 and 35 of the monthly reports. The weekly graphs for August at Lower Monumental are Figure 3, 11, 19, 27 and 35 of the August reports.

Ice Harbor Fish Passage and Survival Test
A two treatment spring spill test to evaluate juvenile fish passage and survival began on April 28 and concluded at 0500 on June 7. The same two treatment spill test (45 kcfs/gas cap vs. 30% of total flow) continued from June 7 as the summer spill test described in the summer FOP, and concluded on July 11. On June 23, the project had to shut a generation unit off for annual maintenance. As a result, the project spilled 35.1 – 43.8% for 15 hours, exceeding the 2009 summer FOP operating range for 30% of total project flow. The objectives of the test were to determine passage routes and estimate route-specific and concrete survival under the two spill conditions for yearling Chinook and steelhead. The spill test alternated between 45 kcfs during the day and spill cap at night, and 30% 24 hours per day with the RSW operating, similar to that used in 2008.

The test resulted in spill ranging from 21 to 181 kcfs, which resulted in TDG levels fluctuating between 102.5 and 123.2% as shown on the weekly graphs in Appendix E. To find the Ice Harbor graphs, see the April report, Figures 4, 8, 16, 24 and 32. The weekly graphs for May June, and July at Ice Harbor are Figure 4, 12, 20, 28 and 36 of the May, June and July reports. The weekly graphs for August at Ice Harbor are Figure 4, 12, 20, 28 and 36 of the August reports.

McNary Spillway Weir Test
A single treatment spring test to evaluate juvenile fish passage and survival under a continuous 40% spill level, with spillway weirs located in spill bays 4 and 20, began on April 18 and continued through June 19. A single treatment summer test under a continuous 50% spill level, with spillway weirs located in adjacent spill bays 19 and 20, began on June 20. The summer test concluded on August 10, while 50% spill operations with spillway weirs in spill bays 19 and 20 continued through August 31. The spillway weir in spill bay 4 was moved to spill bay 19 for the summer test. The primary objective

of the test was to determine the effect of spillway weir location on the behavior, passage distribution, and passage efficiencies of yearling Chinook and juvenile steelhead. The secondary objective of the test was to estimate route specific, dam, and concrete survival of yearling Chinook and juvenile steelhead for the tested configuration and operation.

On July 22, the project began spilling to the TDG spill cap instead of the 50% target spill operation. A System Operational Request (SOR) 2009-03 was discussed and coordinated with TMT on July 22. Project operations were adjusted in response to elevated water temperatures and resulting increased mortality of juvenile salmonids passing through the juvenile bypass system. This operation was in place until July 24 at 1200 when the temperature ranges that fish experienced was reduced. A detailed description was provided to the Court on July 24, 2009. On August 14-17, day average flows were low enough to implement the "low flow" provisions of the 2009 summer FOP forcing the plant to operate for minimum generation requirement instead of the 50% target spill operation.

The test resulted in spill levels ranging from 72 to 363 kcfs which produced TDG levels fluctuating between 101.0 and 122.4% as shown on the weekly graphs in Appendix E. To find the McNary graphs in Appendix E, see the April report, Figures 9, 17, 25 and 33. The weekly graphs for May, June, and July at McNary are Figure 5, 13, 21 and 29 of the monthly reports in Appendix E. The weekly graphs for August at McNary are Figure 5, 13, 21, 29 and 37 of the August report in Appendix E.

John Day Top Spillway Weir Test

A two treatment spring spill test to evaluate juvenile fish passage and survival began on April 27 and concluded on June 4 due to early closure of the spillway weirs. This early closure was a consequence of observed heavy gull predation in the tailrace below the spillway weirs and on June 5, the Court was notified. The two treatment summer test (30% vs. 40%) began on June 25 and concluded on July 20. The spill operation was 30% spill vs. 40% spill 24 hours per day during the test. The objectives of the study were to assess passage distribution and efficiency metrics, forebay retention, tailrace egress, and survival for yearling Chinook, and juvenile steelhead for two spill treatments.

The evaluation resulted in spill levels ranging from 53 to 406 kcfs, which produced TDG levels fluctuating between 97.8 and 121.1% as shown on the weekly graphs in Appendix E. To find the John Day graphs, see the April report, Figures 10, 18, 26 and 34. The weekly graphs for May, June, and July at John Day are Figure 6, 14, 22 and 30 of the May, June and July reports. The weekly graphs for August at John Day are Figure 6, 14, 22, 30 and 38 of the August reports.

4.1.6 Turbine Outages Effecting Spill

On a weekly or daily basis, unit outages will affect the spill volume at the projects. There were no long term unit outages on the lower Snake River but there are twelve turbines on the Columbia River that were out of service from a month or longer:

- McNary: Three units have been out of service for a significant amount of time: Units 7 and 8 were out from June 29 through September 2009 while their transformer was being replaced. Unit 2 was out from July 13 through September 11 for a 9-year overhaul.
- John Day: Unit 4 was out for an overhaul from July 6 through August 20.
- The Dalles: Three units have been out of service for a significant amount of time: Unit 6 was out from March 23 until May 28 for a 5 year overhaul and cavitation repair. Units 7 and 8 have been out for 5 year overhaul and cavitation repair since June 28.
- Bonneville: Five units have been out of service for a significant amount of time: Unit 7 and Unit 9 have remained out of service the entire year for ongoing major repair work. Unit 11 has remained out of service all year due to cracks in the generator rotor. Unit 16 was out of service with a stator ground from May 9 through Sept 28. Unit 6 was out from July 13 through September 10 for a 5-year overhaul.

The above unit outages resulted in additional involuntary spill and only one TDG instance. The Bonneville unit outages resulted in a TDG instance on May 20th.

4.1.7 Voluntary Spill

During most spill seasons, there is voluntary and involuntary spill on the lower Columbia and Snake rivers even during a low water year (e.g. like 2001). Table D-12 in appendix D provides the total outflow (sum of the eight project outflows) for each year with the ten-year total outflow average. Based on the total outflow amounts, the 2009 water years had higher than average total project discharge. Table D-10 shows the amount of voluntary and involuntary spill at each project during the 2009 spill season. The involuntary spill ranged from 2,026 thousand acre feet (Kaf) at Bonneville to none at The Dalles. 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 2009, the voluntary spill called for in the FOP occurred from April 3 to August 31 at the lower Snake River projects and from April 10 to August 31 at the lower Columbia projects. Table D-9 in Appendix D provides the exact amount of voluntary spill that occurred at the various projects during the last 10 years.

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 occur 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 voluntary spill. The amount of voluntary spill for each project is shown in Figures D-1 through D-8 and listed in Tables D-1 through D-8 of Appendix D. Weekly graphs with

FOP spill for April through August are included in the court reports (Appendix E). For more information, the FOP spill can be compared to the TDG levels shown in Appendix E, which contains graphs of spill, flow, and TDG.

4.1.8 Involuntary Spill

Involuntary spill occurred on the lower Columbia River at one or more projects from May 19 through June 11 and from May 19 through June 10 on the lower Snake River. Lower Granite had the most involuntary spill of any of the lower Snake River projects, 1,658 Kaf from May 19 to June 10 (22 days). Little Goose involuntary spill was 551 Kaf from May 19 to June 10 (22 days). Lower Monumental had the least involuntary spill of any of the lower Snake River projects, 494 Kaf from May 19 to June 10 (22 days). Ice Harbor involuntary spill was 1,097 Kaf from May 19 to June 10 (22 days). McNary involuntary spill was 1,180 Kaf from May 20 to June 11 (22 days). John Day involuntary spill was 1 Kaf from May 26 to May 28 (3 days). There was no involuntary spill at The Dalles. Bonneville had the most involuntary spill of any of the Lower Columbia River projects, 2,026 Kaf from May 19 to June 11 (23 days), with an average involuntary spill of 72 kcfs per day.

The FOP spill tables in Appendix D indicate 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.

The impact of high flows on TDG levels was sizeable because of the duration of the high flows and the shape of the runoff. The high freshet flows persisted for 22 days with one single large peak that began May 19 and lasted until June 10. The runoff peak occurred from May 25 to June 4 with daily average flows between 291 and 346 kcfs on the lower Columbia River, which is slightly high compared to previous years. As a result, there were 192 Type 1 condition instances system-wide with 81 Type 1 condition instances on the lower Snake River (Appendix F, Table F-3A) and 111 TDG instances on the lower Columbia River (Appendix F, Table F-3B). Of the total 308 TDG instances system-wide, 192 were due to high runoff flows and flood control efforts. More detailed information on the project specific TDG instances is provided in Part 5 of this report.

Two 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 52 hours of TDG instances over 125%. Lower Granite contributed 51 hours and Bonneville dam contributed 1 hour. The highest hourly reading was at Lower Granite tailwater with 127.4% 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 instance of the 125% TDG standard is provided in Part 5 of this report.

4.2 Use and Development of the SYSTDG Model

SYSTDG is a model used to forecast the TDG levels at the Columbia and Snake River projects and it is used to set daily spill caps, evaluated various spill operations as part of planning or litigation efforts. SYSTDG estimates TDG pressures resulting from project operations on the Columbia from Grand Coulee Dam to Bonneville Dam, Snake River from Lower Granite Dam to the confluence with the Columbia River, and from Dworshak Dam on the Clearwater to its confluence with the Snake River. The parameters of total river flow; spill; wind; water temperature; forebay and tailwater elevations; barometric and total gas pressures; tributary data and spill patterns are incorporated into SYSTDG's forecasts. It also takes into consideration the hydraulic design of the projects, unique river hydrologic conditions and the accumulative effects of project management of the river.

The 2008 Biological Opinion, RPA Action 15 calls for two specific actions associated with the SYSTDG model and they are:

1. "Update the SYSTDG model to reflect modifications to spillways or spill operations"
2. Continued development and use of SYSTDG model for estimating TDG production to assist in real-time decision making, including improved wind forecasting capabilities as appropriate."

Update of the SYSTDG model:

Consistent with RPA Action 15 the following actions occur:

1. Change the spill patterns in the model to the ones used for that year's spill operations.
2. Perform TDG research studies to measure the effects of new spillway structures at the dams such as TSWs or RSWs at Little Goose, Lower Monumental, and John Day.
3. Change the equations in SYSTDG to reflect the results of the TDG research studies.
4. When the National Weather Service installed new weather stations, include them into SYSTDG so the data can be used to more accurately predict TDG levels.
5. Change the TDG calculations of instances when TDG levels exceed state WQS to match the modified state water quality standards changes.

During the 2009 spill season, SYSTDG was updated with the 2009 spill patterns. The results of the TDG research study performed at Chief Joseph Dam in 2009 will be added into the 2010 SYSTDG version. The Corps has not performed TDG research studies to measure the effects of new spillway structures such as TSWs or RSWs at Little Goose, Lower Monumental, and John Day dams, and therefore the TDG production equations in SYSTDG have not been updated to reflect these new structures. Funding is being pursued to study the effects of these new structures in the future.

Use of SYSTDG:
During the 2009 spill season, the RCC Water Quality Team 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 and planning what spill operations should occur at Bonneville Dam in 2010. When total river discharges are so low that the hydro-system is operating at minimum generation, SYSTDG is not used since spill caps are not changed. This low flow period is typically in August but may occur in April, depending on the runoff. When total river discharges are so high that involuntary spill is occurring, SYSTDG is used to set the initial spill caps for 125; 130 and 135% TDG but is not used daily during these high flow periods. When flows are within the range that spill caps are set daily then SYSTDG becomes a very useful tool, which is typically from April through mid May, and from mid June through July. To better evaluate proposed spill caps, RCC Water Quality Team uses the previous years SYSTDG statistical evaluation and the predictive errors for each fixed monitoring station. These predictive errors for the gages are shown on Tables 3 and 4.

The main planning study performed with SYSTDG in 2009 was to evaluate the various summer spill options for Bonneville Dam, including a flat spill of 85 kcfs or 90 kcfs or 95 kcfs or 100 kcfs or 120 kcfs. These spill options were compared against the 2008 BiOp spill operation of 85 kcfs or 75 kcfs during the day and to the gas cap at night. These results will be used to develop a decision for spill management for the 2010 spill season.

Continued Development of SYSTDG:
RPA Action 15 calls for "continued development of SYSTDG model for estimating TDG production to assist in real-time decision making, including improved wind forecasting capabilities as appropriate". SYSTDG is a model to predict TDG levels and it is the Corps perspective that modifying SYSTDG to perform wind forecasting is inappropriate. The Corps is pursuing funding to add new National Weather Service weather stations into SYSTDG which will increase the model's ability to predict the impacts of wind on TDG levels.

A statistical evaluation of SYSTDG was performed in 2009 in an effort to quantify the uncertainty of SYSTDG estimates, obtain the gage predictive error so they can be used to increase the Corps ability to set daily spill caps and improve modeling accuracy and reliability,. The predictive errors were calculated on observed TDG levels during the 2009 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.

Statistical Evaluation of the SYSTDG
The RCC Water Quality Team considered the statistical evaluation of SYSTDG performance in previous years (2004 through 2009) to be highly useful for several reasons:

1. Continuing to use the model as an effective tool in managing spill as directed in RPA Action 15.
2. Provides the predictive error for each FMS gage.
3. Use as part of a peer review process that will establish the model as the TDG model for the Columbia and Snake Rivers.
4. Identify areas for future improvements that can be used to obtain funding to keep the model updated and promote future development as required by RPA Action 15.

The following is a summary of the SYSTDG statistical evaluation for 2009 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 2009 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 observe 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 2009 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^{o}C, the observed forebay TDG pressure was approximated by linearly interpolating between total pressure observations where temperatures were within 0.3^{o}C. A detailed description of model input parameters and coefficients can be found in the SYSTDG user's manual (Corps, 2004).

TABLE 4

Statistical summary of the predictive errors of the observed and calculated total dissolved gas saturation at forebay fixed monitoring station, April 1-August 31, 2009.

		Predictive Error at Forebay FMS* (Saturation %)							
Station		**LGSA**	**LMNA**	**IHRA**	**MCNA**	**JDY**	**TDA**	**BON**	**CWMW**
Number of Observations		3543	3649	3673	3673	3647	3645	3592	3648
Average		0.6	-0.4	0	0.3	0.9	0	0	1.3
Standard Deviation		1.8	1.6	1.2	1.5	1.3	1.2	0.9	1.8
Maximum		5.9	3.1	3.7	5.2	5	4.6	5.1	7.7
Minimum		-4.9	-5.2	-4	-4.3	-4.6	-3.6	-3.1	-2.7
TDG Predictive Error for Percentile Occurrence (mm Hg)	**5%**	-3	-3.8	-2.4	-2.1	-0.9	-1.9	-1.4	-0.5
	10%	-2	-3.1	-1.9	-1.6	-0.6	-1.4	-1.2	-0.4
	25%	-0.5	-1.2	-0.5	-0.8	-0.2	-0.7	-0.6	0
	50%	0.9	0.1	0.2	0.1	0.5	0	0.1	0.7
	75%	1.8	0.8	0.8	1.3	1.6	0.6	0.6	2.4
	90%	2.5	1.3	1.3	2.3	2.9	1.3	1	4.2
	95%	3.1	1.6	1.6	2.8	3.6	2.1	1.2	5.1

*Predictive error is the observed minus calculated TDG saturation where negative values reflect an over-estimation and positive values reflect an under-estimation.

TABLE 5

Statistical summary of the predictive errors of the observed and calculated total dissolved gas saturation at tailwater fixed monitoring stations.

		Predictive Error at Tailwater FMS* (Saturation %)									
Parameters/Stations		**DWQI**	**LGNW**	**LGSW**	**LMNW**	**IDSW**	**MCPW**	**JHAW**	**TDDO**	**CCIW**	**WRNO**
Number of Observations		1353	3322	3243	2893	2158	1551	1517	3431	2799	371
Average		-0.4	-1.5	0	0.1	-0.4	0.4	1.4	-0.8	0.4	-0.1
Standard Deviation		1.7	1.3	1.1	1.7	1	1.1	1.9	1	0.8	0.9
Maximum		3.6	6.2	5.3	6.6	2.3	4.7	5.4	1.8	7.3	2.2
Minimum		-6.2	-4.2	-4.9	-4.8	-3.7	-4	-2.6	-6.7	-1.7	-3
TDG Predictive Error for Percentile Occurrence (mm Hg)	**5%**	-3.6	-3.1	-1.9	-3.7	-2.2	-1.3	-2.6	-0.9	-1.5	-2.2
	10%	-3.2	-3	-1.3	-2.3	-1.8	-0.9	-1.5	-0.6	-1.2	-1.7
	25%	-0.8	-2.6	-0.6	-0.5	-0.8	-0.3	-0.3	-0.1	-0.8	-1.1
	50%	-0.1	-1.6	0.1	0.3	-0.3	0.2	1.1	0.4	-0.1	-0.5
	75%	0.7	-0.5	0.7	1.1	0.3	1	2.7	0.8	0.6	0.3
	90%	1.4	0.4	1.3	2	0.8	1.9	4.3	1.4	1.2	1.1
	95%	1.6	0.8	1.8	2.3	1.1	2.4	4.7	1.8	1.4	1.4

*Predictive error is the observed minus calculated TDG saturation where negative values reflect an over-estimation and positive values reflect an under-estimation.

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 in 2009 (Tables G5 and G6) were slightly larger than predictive errors estimated at tailwater stations (Tables G7 and G8). A review of model performance indicates that 6 out of the 8 forebay station has standard error greater than 10 mm Hg compared to only 3 out of 9 tailwater stations. The average predictive errors at forebay stations were less than 1% of saturation with the exception of Ice Harbor Dam and the Camas/Washougal mixed river station. The overestimation of forebay TDG pressures at the Camas/Washougal station was attributed to misrepresenting the production of TDG associated with the B2CC outfall. The correlation between strong winds and declining TDG pressure at forebay stations was again evident during the 2009 spill season. In several reaches, the considerations of wind direction and magnitude of wind will identify co-flowing and counter-flowing conditions that may improve the estimation of TDG off-gassing during passage through a given river reach.

- The TDG exchange, transport, and mixing of Bonneville Dam releases during the 2009 spill season proved to be reliably modeled during higher flow conditions from April through June. The low flow conditions at Bonneville proved to be much more problematic for estimating the hourly TDG properties at the Camas/Washougal FMS during periods in July and August. The under estimation of TDG levels in the Columbia River at the Camas/Washougal mixed river station have proven to be problematic during low flow conditions in other years. The likely source of the error in estimate at CWMW is the contribution of TDG pressure associated with the Bonneville 2nd powerhouse corner collector. The low flow condition places much greater importance on secondary sources of TDG pressure. The low tailwater stage is likely to result in a B2CC outfall jet that entrains air at a high rate, plunges deeply into the receiving channel, and entrains significant quantities of flow bounding the plunge pool. An alternative TDG production model was proposed for the B2CC outfall that is a function of tailwater elevation. This formulation provided more reliable estimates of TDG pressure at the Camas/Washougal monitoring station during low flow conditions when the B2CC was operational. The TDG production characteristics observed at Bonneville Dam tailwater station (CCIW) during the 2009 spill season were closely simulated throughout the spill season as indicated by the standard error of estimate of 6.1 mm Hg. The spillway capacity as limited by TDG saturations of 120% were observed to range from 95 to 140 kcfs during the 2009 spill season. The TDG pressures in the Columbia River at the Warrendale fixed monitoring station continue to provide reliable estimates of the aggregate TDG loading of releases from Bonneville Dam for TDG management during the winter and spring time.

- The modeling of TDG exchange at The Dalles Dam and throughout the Bonneville pool proved again 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 7.2 mm Hg while the corresponding standard error in the forebay of Bonneville Dam was only 6.5 mm Hg. The reason for the more reliable estimates of TDG pressure in the forebay of Bonneville Dam when compared to the tailwater station below The Dalles Dam is likely attributed to the greater variability in hourly operations at the dam. The tailwater monitoring station at The Dalles Dam resides in mixed waters influenced by both powerhouse and spillway flows. This mixed river sampling station masks the higher TDG pressures generated in spillway releases that were estimated to range from 122 to 127% of saturation. There was no indication that the TDG generation properties at The Dalles Dam has changed noticeably during the construction of the spillway training wall between spill bays 8 and 9.

- The spill patterns at John Day Dam were changed during the 2009 spill season involving a spring pattern featuring the operation of two temporary spillway weirs in spill bays 14 and 15 and a summer spill pattern employing a uniform spill pattern over bays 2-13. The spring bulk spill pattern has altered the TDG exchange patterns at John Day Dam where the TDG contributions from the TWS's are masked for high flows but become more evident at lower spill discharges. The spring spill pattern called for higher surface discharges through the two TSW's to support fish guidance past John Day Dam. The summer spill pattern resulted in higher TDG pressures when compared to the spring pattern at the same total spillway flow. The simulations for TDG exchange and transport from John Day Dam did not anticipate the implementation of the summer spill pattern at John Day Dam resulting in a sizable under-estimation bias in the TDG generation as monitored at the tailwater fixed monitoring station. However, when model inputs were updated to reflect the applied spill patterns, both the model bias and standard error were significantly reduced to levels comparable to other projects. The SYSTDG model estimates can be used to screen TDG data collected from the fixed monitoring network as evidenced by the declining drift in TDG pressure recorded at the tailwater fixed monitoring station at John Day Dam in May. The spillway capacity as limited by the 120% TDG saturation criterion is considerably less using the summer spill pattern (as low as 80 kcfs) compared to the spring spill pattern (120 kcfs lower bound). The fate of powerhouse flows with the alternative spill patterns continues to be an uncertain component in estimating the TDG loading associated with John Day Dam releases.

- The operations at McNary Dam involved spilling water through a couple of TSW's throughout the entire fish passage season. The location of these spill bay control structures changed in 2009 being located in spill bays 6

and 19 during the spring and bays 18 and 19 during the summer. The TDG pressures observed at the tailwater fixed monitoring station were a function of the spill pattern and usage of the TSW's. The spring spillway configuration generated consistently higher TDG pressures than the summer configuration for spill discharges of 75 kcfs and greater. The spring spill pattern resulted in tailwater TDG pressures that were typically 10-20 mm Hg higher than the summer spill pattern. The difference in tailwater stage and effective depth could account for some of the differences between the two patterns. There was insufficient data collected at McNary Dam to evaluate the change in spillway capacity as limited by the TDG criterion of 120%. The summer spillway configuration resulted in increasing TDG pressures at the tailwater FMS for spillway discharges falling below 85 kcfs. This property was likely related to the mixing zone from the TSW releases reaching the north shore during lower spillway discharges. The continuously declining TDG pressures at lower spill discharges for the spring spillway configuration maybe related to the shallow tailwater conditions downstream from the northern end of the stilling basin. The SYSTDG simulation of tailwater TDG pressures at McNary Dam were reliable (standard error of 8.1 mm Hg, average error of 2.7 mm Hg) during the fish passage season even with the variable location of the TSW's. The TDG estimates in the forebay of John Day Dam were improved over conditions in 2008. The mean and standard error in the forebay of John Day Dam were 3.8 and 10.2 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 TDG exchange formulation for Ice Harbor Dam provides one of the most reliable estimates of tailwater TDG pressure for the Snake River with a mean error estimate of -2.8 mm Hg and a standard error estimate of 7.5 mm Hg. The consistent performance of this TDG exchange model is related to the importance of tailwater depth of flow on TDG generation. 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 55.2% 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 TDG production at Lower Monumental Dam has consistently been a poor performer in the modeling of TDG pressures in the Snake River as was the case again in 2009. The tailwater TDG pressures were systematically under estimated with a mean error of estimate of 16.3 mm Hg throughout the spill season. The complexity in the TDG exchange characteristics at Lower Monumental Dam involves a complex spill

pattern and the substantial entrainment of powerhouse flows into aerated spillway flows. An alternative TDG production formulation was developed consisting of the simple product of the tailwater depth of flow and square root of the specific spillway discharge that demonstrated a significant improvement in the estimation of TDG exchange. The determination of the effective number of spill bays is a critical component in determining the specific spill discharge in the TDG exchange formulation. The observed TDG saturation at the tailwater FMS was found to be function of the forebay TDG saturation for small total river flows requiring reformulation of powerhouse entrainment. 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 24.9% of the time.

- The structural configuration of the spillway at Little Goose Dam were altered significantly prior to the 2009 spill season with the construction of spillway flow deflectors on bays 1 and 8 along with the installation of a removable spillway weir in spill bay 1. The concentration of spill in bay 1 was observed to have a significant influence over the tailwater TDG pressures during moderate total river flows and low background TDG levels when compared to uniform spill over bays 2-8. The influence of RSW spill at higher river flow conditions is likely to diminish because of more comparable specific discharges from other bays. The tailwater FMS TDG pressures at Little Goose Dam have been found to be a function of both powerhouse and spillway releases because of the prominent interaction of spillway and powerhouse flow in the tailrace of the dam. The application of the existing TDG exchange formulation for Little Goose Dam preformed well based on the new structure and spill pattern was a mean and standard error of estimate of 0.3 and 8.4 mm Hg respectively. A noted short coming of model predictions during the 2009 season involved the estimation of TDG pressures during peak spillway discharges. The initial review of tailwater TDG data suggest the new spillway flow deflectors perform similarly to the original deflectors in terms of TDG exchange.

- The SYSTDG model provided reliable estimates of TDG exchange at Lower Granite Dam during the 2009 spill season with the exception of estimates of the standard fish spills of 20 kcfs and less. The model over estimated the tailwater TDG pressures for small spill discharges to a degree that was uncharacteristic at Lower Granite Dam. The probable cause for these predictive errors is the development of the mixing zone at low percent river spill conditions resulting in powerhouse releases influencing tailwater FMS observations. The TDG generation errors at Lower Granite Dam likely contributed the larger standard errors in the forebay of Little Goose Dam.

- Dworshak Dam conducted both spillway and regulating releases to manage pool filling and drafting actions during the 2009 spill season. The highest TDG levels observed at the tailwater FMS were generated during a modest spill of 3.7 kcfs during limited powerhouse flows. The tailwater station below Dworshak Dam resides in mixed waters and is influenced by both powerhouse and spillway/RO releases. A challenge in providing estimates of TDG exchange in releases from Dworshak includes providing estimates of the TDG content in powerhouse flows. The scheduling of sequential regulating outlet and spillway discharge events in 2009 with the same powerhouse flows suggests the spillway produces lower TDG pressures than a comparable regulating outlet release. The elevation of Clearwater River TDG pressures during single turbine operations were noted during the 2009 season. The turbine discharges that generate TDG supersaturation fall at the lower operating range for each turbine but specific operating zones of high rates of air entrainment are apparent.

4.2.3 Future Improvements Identified

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

- The hourly description of the applied spill pattern should be optional input on each project page. This feature has been implemented on a trial basis and includes the designation of the number of effective spill bays in operation at any given hour. The effective number of spill bays is subsequently used to calculate the specific discharge. The effective number of spill bays has been estimated from the proscribed spill pattern using the following formulation.

$$nbays = \frac{\sum_{i=1}^{i=NB} q_i \sum_{i=1}^{i=NB} q_i^{N-2}}{\sum_{i=1}^{i=NB} q_i^{N-1}}$$

Where

q_i = spillway flow in bay i (kcfs)
NB = Total number of spill bays
N = weighting coefficient (N=1 arithmetic average, N-2 flow weighted)

- The weighting of individual spill bays is important when bulk spill patterns are used and the effects of certain bays may over ride the influence of training spill bays flows at moderate to small flows.

- The evaluation of the TDG exchange properties at Little Goose Dam with the modified structure and spill pattern is loosely defined using a single monitoring station below the dam. A much more rigorous evaluation of spillway flow deflectors, RSW, and alternative spill patterns at Little Goose Dam should involve additional field sampling.

- The alternative TDG exchange formulation for Lower Monumental Dam should be investigated with additional data from other years. The identification of the influence of forebay TDG pressures on data observed at the tailwater FMS should be quantified.

- The influence of TSW on TDG production should be quantified at John Day and McNary Dams. The potential for TSW's to influence entrainment of powerhouse flows and create local regions of elevated TDG pressure undetected by the tailwater FMS will require additional field sampling.

- The proposed TDG exchange formulation for the Bonneville 2nd powerhouse corner collector should be evaluated with data form previous years. The potential for other secondary sources of TDG supersaturation should be explored such as the 1st Powerhouse ice and trash outfall or the Bonneville 2nd powerhouse juvenile bypass outfall.

- The impacts of wind speed and direction should be examined as an improved description of TDG exchange with the atmosphere. The generation of breaking wave by co-flowing and counter-flowing wind and water currents may result in a better description of degassing. The use of multiple weather stations for long pools may also improve model estimates.

- The identification of consistent sampling bias at tailwater fixed monitoring stations should be documented and incorporated into management activities.

- The statistical computation of the new daily Washington compliance metric for TDG saturation should be implemented in SYSTDG.

Part 5 Instances of TDG Exceeding WQS

5.1. Change in TDG Instance Calculation Methods

In previous years, the States of Oregon and Washington specified the method of calculating the "daily percent TDG" as an average of the 12 highest hourly readings in a given day. For the purposes of this report, this method of calculating the high 12 hour averages is called the Oregon/Washington method. Since 2006, both states have changed their methods for calculating the high 12 hour average. In November 2006, Washington DOE changed their method of calculating percent TDG to involve using a running consecutive 12-hour average. The daily high consecutive 12-hour TDG level is determined as the highest of the average value of each preceding 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". In 2008, as a result of the Adaptive Management Team meetings, Oregon determined that 115% TDG standard and forebay gages are not needed to assess acceptable TDG levels in the lower Columbia River. As a result, Oregon DEQ no longer requires TDG monitoring at forebay gages and their revised method of calculating the "daily percent TDG" to an average of the 12 highest hourly readings in a given day for tailwater gages only. For the purposes of this report, this method is called the Oregon method of calculating the 12-hour TDG.

It was agreed that the Corps would evaluate the Washington method of calculating the consecutive 12-hour average in 2008 and 2009 and compare it against the Oregon/Washington method of high 12-hour average. An evaluation and discussion of the two methods are provided in section 5.3 of this report.

Since the 2008 Biological Opinion is in litigation, the Corps projects were operated consistent with the U.S. District Court of Oregon Order, which means, the previous TDG monitoring system, with forebay gages and the method of calculating the 12 hour average used in 2007 continued through 2009. As a result, the Oregon/Washington method of TDG instances was used for spill management. Neither the new Oregon nor Washington methods of calculating TDG instances were used for 2009 spill management.

5.2 TDG Instances – Oregon/Washington Calculations

5.2.1 115% and 120% TDG Instances

The Corps tracks the number of instances that the high 12 hour average TDG levels exceeded WQS during spill season for both the Oregon/Washington and Washington methods of calculating TDG instances. Since the Oregon/Washington method of calculating TDG instances was used in 2009 spill management, the TDG instance discussion uses that method.

During the 2009 spill season, there were 308 instances out of 2,504 days at the projects on the lower Columbia and Snake rivers ([number of TDG gages] x [days in spill season, April 3 through August 31]) in which the TDG levels were above the Oregon/Washington

TDG criteria. There were 192 instances of a Type 1 condition, which the Corps could not prevent. The other 116 TDG instances were Type 2 and 3 instances as discussed in Table 8. The 308 instances in which the TDG levels were above the Oregon/Washington high 12-hour average criteria was slightly higher than the 270 eleven-year average TDG instances for a spill season. Table 6 provides a summary of TDG instances for 1999 through 2009 spill seasons. The 308 Oregon high 12-hour average TDG instances during 2009 spill season are represented during both voluntary and involuntary spill.

As indicated in Table 6, the Camas/Washougal, Ice Harbor forebay, and Bonneville forebay FMS had the highest number of high 12-hour average TDG instances during 2009 and were the most difficult to maintain below the 115% or 120% TDG standard.

The Camas/Washougal gage had 66 TDG instances, which was the most in the FCRPS system with 19 Type 1 conditions, which are associated with high flows and flood control efforts. The Ice Harbor forebay station recorded 44 TDG instances with 17 Type 1 conditions, the second most TDG instances of the FMS system monitoring stations during 2009. The Bonneville forebay station recorded 32 TDG instances with 10 Type 1 conditions, the third most TDG instances of the FMS system monitoring stations. The Lower Monumental forebay station recorded 26 TDG instances with 24 Type 1 conditions, the fourth most TDG instances of the FMS system monitoring stations.

Camas/Washougal is typically a location that records a higher number of instances than other FMS locations and 2009 was no exception. The Ice Harbor forebay gage registering the second most TDG instances is typically, as indicated in Table 6. The Bonneville forebay gage registering the third most TDG instances is unusual. Table 6 shows that Bonneville forebay gage, has not been among the top four gages with the most instances in the last 11 years. The Lower Monumental forebay gage registering the fourth most TDG instances is typical. For further discussion of the individual gages that have high TDG instances, see section 5.2.5 of this report.

TABLE 6
1999 - 2009 SPILL SEASONS
NUMBER OF TDG INSTANCES
OF HIGH 12 HOUR AVERAGES EXCEEDING WQS

INSTANCES OF AVERAGE HIGH 12 HR %TDG EXCEEDING WQS AT FMS FROM 1999 - 2009												
Water Quality Gages	2009	2008	2007	2006	2005	2004	2003	2002	2001	2000	1999	11 year
	Qty.	Qty.	Qty.	Qty.	Qty.	Qty.	Qty.	Qty.	Qty.	Qty.	Qty.	Avg
Lower Granite Forebay	0	0	0	0	0	0	0	0	5	2	0	1
Lower Granite Tailwater	15	35	0	28	0	0	15	17	0	4	15	13
Little Goose Forebay	19	34	0	24	0	3	10	17	0	2	39	15
Little Goose Tailwater	0	23	0	19	0	0	6	6	0	9	6	7
Lower Monumental FB	26	54	11	56	6	1	19	49	0	28	44	29
Lower Monumental TW	21	32	7	29	7	1	10	6	0	12	26	15
Ice Harbor Forebay	44	55	31	51	3	4	35	24	0	34	44	33
Ice Harbor Tailwater	25	31	0	22	3	2	4	6	0	4	12	11
McNary Forebay - WA	4	21	6	31	8	10	24	43	1	14	22	18
McNary Forebay - OR	--	--	--	--	11	23	32	45	5	22	19	16
McNary Tailwater	5	28	1	32	1	7	12	31	0	17	50	18
John Day Forebay	9	14	0	20	2	0	10	11	0	1	8	8
John Day Tailwater	7	17	3	38	3	0	0	29	0	12	43	15
The Dalles Forebay	11	17	8	40	6	5	11	18	0	5	1	12
The Dalles Tailwater	0	2	0	10	0	0	4	11	0	5	5	4
Bonneville Forebay	32	27	3	51	3	1	17	30	0	14	19	20
Cascade Island *	24	57	0	61	0	---	---	---	---	---	---	36
Warrendale	--	--	--	--	---	0	1	19	0	6	2	3
Camas/Washougal	66	68	29	63	16	14	33	65	2	58	51	47
Total Number of Exceedances	**308**	**515**	**99**	**575**	**69**	**71**	**243**	**427**	**13**	**249**	**406**	**270**

5.2.2 Instances of TDG Exceeding 125% WQS

During the 2009 spill season, there were 52 instances of hourly TDG exceeding either the Oregon or Washington state standards of 125% TDG (a one hour standard in Oregon and a two hour standard in Washington). 2009 had a low number of 125% hourly TDG instances compared to the last eleven years since 2001 when the hourly instance tracking began (Table F-5 in Appendix F). Involuntary spill due to high runoff resulted in all 52 hours of 125% instances of the Oregon standard and was the number one factor that contributed to the number of these occurrences. Aspects of the high runoff that influenced the instances 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 2009, high runoff occurred in May through mid June allowing the full effects of involuntary spill on TDG levels, resulting in more 125% hourly TDG instances.

In 2009, there was one special spill operation to pass woody debris at Lower Granite that contributed to the number of 125% TDG instances. On May 22 excessive debris at Lower Granite entered the collection system and clogged the incline dewatering screen temporarily stopping fish collection and routine transport. These conditions caused injury and mortality to fish present in the collection system (screens, raceways and sampling tanks). NOAA Fisheries and TMT representatives were notified of the change in operations on May 22. Corps personnel calculate that a total of over 500,000 juvenile salmonids passed Lower Granite on May 22 with a total of 721 juvenile fish mortalities associated with the debris conditions. Collection for transport operations at Lower Granite resumed on May 25 once debris levels subsided with notification to TMT representatives on May 26. During this debris spill, TDG levels ranged from 122.1 to 125.8% and exceeded 125% for one hour.

There were two other events of woody debris at Lower Granite and Little Goose although they did not generate TDG levels of 125% or higher. On June 14, Lower Granite had to increase spill to pass excessive debris through the spillway bay. As a result, the project spilled 22.3 kcfs for one hour, exceeding the 2009 Spring FOP operations of 20 kcfs spill cap. At Little Goose, on June 10, an unplanned powerhouse outage occurred due to excessive debris that required units to be cleaned and inspected for damage. As a result, the project spilled 38.4 and 34.8 kcfs for two hours, exceeding the 2009 Spring FOP operations of 30 kcfs spill cap.

5.2.3 Comparison of Annual Daily Instances

A comparison of the 2009 daily instances of TDG exceeding WQS to the eleven-year average shows that 2009 had a slightly higher number of daily instances than the eleven year average. As indicated in Table 6, there were 308 daily TDG instances in 2009. As indicated in Table 7, the eleven year average is 257 and by comparison, 2009 had 20% more daily instances than the eleven-year average. This high number of daily TDG instances is attributed to high flows and the shape of the runoff. Even though the January through July percent of normal runoff at The Dalles was in the "below average" range with 84% of normal (1971 - 2000), and the April, May and June runoff was below average, the shape of the runoff was one single peak that lasted three weeks resulting in a high number of daily instances. The shape of the runoff can be observed in the percentages of normal that are shown on Table 1 (page 15 of this report).

TABLE 7
SUMMARY COMPARISON OF DAILY INSTANCES OF TDG EXCEEDING WQS WITH PREVIOUS YEARS

Year	Days In Spill Season	Number of Days of Instances	Percent of Days Exceeding TDG Standard (%)	Percent of Days Consistent With TDG Standard (%)	% of Normal runoff at TDA [1]
2009	2504	308	12.3	87.7	84.1
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: 2006-2009: Number of spill days based on 8 gages x 151 days plus 9 gages x 144 days.

Note: 2000-2005: Number of spill days are based on 18 gages X 153 days from April 1 - August 31

(2006-2009: Spill season started Apr 3 for L. Snake R. and April 10 for L.Col R).

5.2.4 Type of Daily TDG Instances

Since 2003, the Corps has been requested to track the causes of daily high 12-hour average TDG exceeding WQS. From 2002 to 2008, 14 instance types were used and in 2009 the definitions were condensed to three types, which included all the previous 14 instance

types. Table F-1 of Appendix F provides a listing of the three causes (types). The Corps tracked the daily TDG instance types for the forebay and tailwater of each Corps project during the 2009 spill season. Each type of instance represents conditions that cause daily TDG levels to exceed WQS. The 2009 tracking results are shown on Table 8, which also provides a summary of the types of daily instance tracking results from 2003 through 2009 spill seasons. A more detailed list of when and where the daily instance 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 instance types at each project. The daily instance type designation given to each TDG instance is based on the Corps subjective determination of causation.

During the 2009 spill season, TDG instances were attributed to several causes and they are listed in order of highest to lowest number of occurrences in Table 8:

1. TDG levels exceed the TDG standard due to exceeding powerhouse capacity at run-of-river projects resulting in spill above the BiOp fish spill levels. This condition type includes: High runoff flows and flood control efforts; BPA load requirements are lower than actual powerhouse capacity; and involuntary spill at Mid Columbia or lower Snake river dams resulting in high TDG levels entering the lower Columbia River. (191 Type 1 conditions)
2. Planned and unplanned outages of hydro power equipment including generation unit, transmission line, or powerhouse outages. (1 Type 1a conditions)
3. TDG instances due to the operation or mechanical failure of non-generating equipment. (1 Type 2 instance type)
4. Malfunctioning FMS gauge, resulting in fewer TDG or temperature measurements for setting TDG spill caps. (17 Type 2a instance type)
5. TDG instances due to uncertainties when using best professional judgment, SYSTDG model and forecasts. (98 Type 3 instance type)

Certain trends were observed from the 2003 – 2009 TDG instances tracking data as summarized in Table 8. For example, the types of instance listed in Table 8 typically occur 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 instances when possible.

The majority (62.0%) of the 308 TDG instances were caused by the high runoff flows and flood control operations in 2009. Because the shape of the runoff was one intense peak, the flows were high during the freshet and resulted in many days of involuntary spill.

TABLE 8
2003-2009 SPILL SEASONS
TYPES AND NUMBERS OF TDG INSTANCES

7 Year Average	2009	2008	2007	2006	2005	2004	2003	TYPE #	DEFINITION
175	191	422	6	486	29	7	86	**1**	TDG levels exceed the TDG standard due to exceeding powerhouse capacity at run-of-river projects resulting in spill above the BiOp fish spill levels.
7	1	1	1	45	0	0	0	**1a**	Planned and unplanned outages of hydro power equipment including generation unit, intertie line, or powerhouse outages.
7	1	11	0	14	1	6	17	**2**	TDG exceedances due to the operation or mechanical failure of non-generating equipment.
6	17	10	0	1	1	6	7	**2a**	Malfunctioning FMS gauge, resulting in fewer TDG or temperature measurements for setting TDG spill caps.
85	98	81	93	75	39	48	159	**3**	TDG exceedances due to uncertainties when using best professional judgment, SYSTDG model and forecasts.
280	**308**	**525**	**100**	**621**	**70**	**67**	**269**		**Totals**

5.2.5 Recurring High TDG Instances

Historically there are three FMS locations that are difficult to manage to avoid TDG instances from voluntary and/or involuntary spill and as a result, record high recurring TDG instances in most years. These three sites are Camas/Washougal, Ice Harbor forebay and Lower Monumental forebay. A review of the 1999-2009 daily TDG instances summarized in Table 6 indicates the Camas/Washougal, Ice Harbor forebay and Lower Monumental forebay have a history of recurring daily TDG instances and these gages continued to be high recurring instances sites. These three gages have the highest eleven-year average number of daily TDG instances. As Table 6 indicates, the other gages' eleven year average number of daily TDG instances is far less than these three gages. These FMS sites typically have high TDG instances as a result of high flows and unit outages. From a historical perspective, these historical trends persisted into 2009.

In 2009, the Bonneville forebay gage was among the top four TDG instance sites for the first time in the last eleven years. The Bonneville forebay gage 11 year average number of TDG instance is 20, which is the fifth highest out of 19 gages. The following is a discussion about each of these high TDG instance gages.

5.2.5.1 Camas/Washougal

Historically, the Camas/Washougal FMS typically records the highest number of daily TDG instance, as was the case in the 2009 spill season. As indicated in Table 6, Camas/Washougal had the most daily TDG instances during the 2009 spill season with 19 Type 1 conditions and 47 Type 3 TDG instances; the most during the last eleven years (1999 – 2009) with an average of 47 daily TDG instances per year. The Camas/Washougal FMS represents a theoretical forebay for 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. With the construction of The Dalles spillwall, it was necessary to use a bulk spill pattern to minimize damage, and therefore higher than usual TDG levels arriving at the Bonneville forebay, which added to the river TDG load. 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 instances at this gage are usually classified as Type 3 instances: "TDG instances due to uncertainties when using best professional judgment, SYSTDG model and forecasts, which include uncertainties when using best professional judgment to apply the spill guidance criteria, e.g., travel time, degassing, and spill patterns, uncertainties when using the SYSTDG model to predict the effects of various hydro system operations, temperature, degassing, and travel time, uncertainties when using forecasts for flows, temperature and wind; unanticipated sharp rise in water temperature (a 1.5^{o}F. or greater change in a day) and bulk spill pattern being used which generated more TDG than expected." In most years, the TDG instances were classified as Type 3 instances. In some years when the precipitation and runoff are high, the TDG instances at the Camas gage will be classified primarily as Type 1 condition, due to high runoff and flood control operations.

5.2.5.2 Ice Harbor Forebay

Historically, the Ice Harbor forebay FMS has a high number of daily TDG instances. This trend continued in the 2009 spill season. As indicated on Table 6, the Ice Harbor forebay recorded the second highest number of daily TDG instances during the 2009 spill season. There were a total of 44 instances: 25 Type 1 condition, and 19 Type 3 instances. This was also the second highest during the last 11 years, at an average of 33 daily TDG instances per year. Historically, the Ice Harbor forebay is among the top TDG instance FMS site locations. The frequency of instances 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's forebay TDG instances. The cumulative impacts of spill operations on the Snake River also contribute to the higher TDG in the river as the water moves downstream.

5.2.5.3 Bonneville Forebay

Historically, the Bonneville forebay FMS has the fifth most daily TDG instances in the FCRPS system but in 2009, the gage moved up to third place among the traditionally high exceeding gages. As indicated on Table 6, the Bonneville forebay recorded the third highest number of daily TDG instances during the 2009 spill season with 10 Type 1 conditions, 2 Type 2a instances, and 18 Type 3 TDG instances. Type 1 condition instances are associated with high flows and flood control efforts so these are typical. The Type 2a instances are associated with malfunctioning gages. It is the Type 3 instances which are associated with uncertainties when using best professional judgment, SYSTDG model and forecasts that were higher than usual. The high number of Type 3 TDG instances is attributed to the construction of The Dalles spillwall and the necessity to use bulk spill patterns that generated higher than normal TDG levels.

5.2.5.4 Lower Monumental Forebay

Historically, the Lower Monumental forebay FMS has recorded a high number of TDG instances. This trend continued in the 2009 spill season. As indicated on Table 6, the Lower Monumental forebay FMS recorded the fourth most number of TDG instances (26) with 24 Type 1 conditions, and 2 Type 3 TDG instances. 24 Type 1 condition instances indicates that the majority of Lower Monumental forebay TDG instances are caused by high flows and flood controls efforts at Little Goose and high TDG levels arrive at Lower Monumental.

5.3 TDG Instances – Washington Calculations

In November 2006, Washington DOE changed their method of calculating percent TDG to involve using a running consecutive 12-hour average. The daily high consecutive 12-hour TDG level determined as the highest of the average value of each preceding 12-hour interval for each hour of the day. This results in a calculated daily value that can span over two days. The Corps operations were consistent with the U.S. District Court of Oregon Order, which means, the previous method of calculating the 12 hour average used in 2007 (Oregon/Washington method) continued through 2009. The new Washington method will be used for spill management when there are no restrictions from litigation. It is understood that the Corps should use the new Washington method to average and report the 12 consecutive hourly high TDG reading in a day beginning with the 2008 spill season. Therefore Section 5.3 reports on the Washington method of calculating TDG instances to fulfill that requirement.

5.3.1 115% and 120% TDG Instances

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 instances for the 2009 spill season using this method. Table 9 shows the number of TDG instances for 2009 per to the new Washington method of calculating the high 12-hour average TDG. Table 9 also compares the new Washington method to the old method which is referred to as the Oregon/Washington method.

TABLE 9
2009 SPILL SEASON TDG INSTANCES
COMPARISON OF WA AND OR/WA METHODS

Water Quality Gages	WA - 2009 Qty.	OR/WA - 2009 Qty.	Difference Qty.
Lower Granite Forebay *	0	0	0
Lower Granite Tailwater	16	15	1
Little Goose Forebay *	21	19	2
Little Goose Tailwater	0	0	0
Lower Monumental Forebay *	30	26	4
Lower Monumental Tailwater	20	21	-1
Ice Harbor Forebay *	47	44	3
Ice Harbor Tailwater	28	25	3
McNary Forebay - WA *	**6**	4	2
McNary Forebay - OR	--	--	--
McNary Tailwater	**5**	5	0
John Day Forebay	**11**	9	2
John Day Tailwater	**7**	7	0
The Dalles Forebay	**13**	11	2
The Dalles Tailwater	0	0	0
Bonneville Forebay	39	32	7
Cascade Island	25	24	1
Warrendale	--	--	--
Camas/Washougal	78	66	12
Total Number of Instances	**346**	**308**	**38**
Tailwater Instances	**101**	**97**	**4**
Forebay Instances	**245**	**211**	**34**

5.3.2 Comparison of Washington and Oregon Calculation Methods

As Table 9 indicates, there were 346 TDG instances during 2009 spill season per the Washington method. This is 33 more TDG instances than the Oregon/Washington method (308). The fact that the Washington method resulted in 33 additional TDG instances shows that it is more stringent. As Table 9 shows, these 34 additional TDG instances occurred primarily at project forebay gages, with the Camas Washougal gage having an additional 12 instances, the largest number of additional TDG instances for any gage. The additional TDG instances at the other forebay gages ranged from 0 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/Washington method of calculating TDG instances resulted in the tailwater gages TDG instances ranged from a loss of 1 to a gain of 2. These results suggest that the Washington method of calculating TDG instances 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 instance compared to the Oregon method were the Cascade Island tailwater and Lower Monumental tailwater gages.

TABLE 10
FOREBAY GAGES MOST EFFECTED BY CHANGING CALCULATION METHODS

Water Quality Gages - Forebay	WA - 2009 Qty.	OR/WA - 2009 Qty.	Difference Qty.
Camas/Washougal	78	66	12
Bonneville Forebay	39	32	7
Lower Monumental Forebay	30	26	4
Ice Harbor Forebay	47	44	3
McNary Forebay	**6**	4	2
John Day Forebay	**11**	9	2
The Dalles Forebay	**13**	11	2
Lower Granite Forebay	0	0	0
Little Goose Forebay	21	19	2
Total Number of Instances	**245**	**211**	**34**

Part 6 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 I contains a summary of the Dworshak flow augmentation and cool water releases operations with graphs of Dworshak and Lower Granite tailrace water temperatures. Appendix E contains temperature graphs that were in the court order spill reports.

Appendix H Table H-1, shows water temperature information from a broad perspective, providing the number of days that temperatures were above 68°F on a daily average, the date this condition began, when it ended and other general information. Table 11 shown below provides a five year comparison of the number of days that a gage recorded temperatures above 68°F on a daily average from 2005 through 2009. As Table 11 shows, 2009 water year was about average and the 2008 water year was a cooler than average.

TABLE 11
NUMBER OF DAYS GAGES RECORDED TEMPERATURES ABOVE 68 DEGREES F ON A 24 HR AVERAGE

Location	2009	2008	2007	2006	2005
	Number of days	Number of days	Number of days	Number of days	Number of days
LBQM	0	0	0	0	0
ALFI	54	42	29	70	50
ALQI	54	38	64	70	---
CHJ	0	0	0	0	0
CHQW	0	0	0	0	0
ANQW	76	49	78	76	65
DWQI	0	0	0	0	0
PEKI	0	0	0	0	0
LEWI	0	0	0	0	0
LWG	3	0	1	5	53
LGNW	0	0	1	8	0
LGSA	25	7	35	51	20
LGSW	18	6	34	48	20
LMNA	36	13	58	59	40
LMNW	31	14	59	59	44
IHRA	61	32	66	68	56
IDSW	62	36	68	69	60
PAQW	38	12	28	38	27
MCNA	60	27	63	59	49
MCPW	65	29	65	61	50
JDY	60	39	72	68	55
JHAW	70	41	72	68	55
TDA	63	34	69	67	56
TDDO	70	38	69	67	56
BON	62	27	65	64	56
CCIW	65	27	65	65	55
CWMW	65	34	66	65	58
Total	**1,038**	**545**	**1,127**	**1,205**	**925**

6.1 Dworshak Summer Operations

The NOAA Fisheries 2008 BiOp, RPA Actions 4 and 15 calls for with the following Dworshak Project operations:

RPA Action 4 – Storage Project Operations:

1. Operate to standard flood control criteria; shift system flood control to Grand Coulee when possible, unless modified by Hydro Strategy 1, Action 14 (Dry Water Year Operations).
2. When not operating to minimum flows, operate to reaching the upper flood control rule curve on or about April 10 (the exact date to be determined during in-season management) to increase flows for spring flow management.
3. Provide minimum flows while not exceeding Idaho State TDG water quality standard of 110%.
4. Refill the reservoir by about June 30 to 1600 ft.

5. Draft the reservoir to elevation 1535 feet by the end of August and elevation 1520 feet (80 feet from full) by the end of September unless modified per the Agreement between the U.S. and the Nez Perce Tribe for water use in the Dworshak Reservoir.
6. Regulate outflow temperatures to attempt to maintain water temperatures at Lower Granite tailwater at or below the water quality standard of 68° F.
7. Maximum project discharge for salmon flow augmentation to be within state of Idaho TDG water quality standards of 110% (There will be expansion of a water temperature modeling program with CE-QUAL-W2).

RPA Action 15 – Water Quality Plan:

8. Continued development of the CE-QUAL-W2 model for estimating river temperatures from Dworshak Dam on the Clearwater, Middle Snake River near the confluence with the Grand Ronde River (USGS Anatone gage) and through the lower Snake River (all four Corps lower Snake River projects). The model results are used to assist in real-time decision making for Dworshak Dam operations.

Throughout the 2009 water-year, releases from Dworshak are managed for both flow augmentation and temperature control. From mid-September through June, releases from Dworshak are 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. Figure I-5 in Appendix I show how cool water releases from Dworshak cooled temperatures for the lower Snake projects. The Corps achieved the RPA Action 4 objective of using cold water releases from Dworshak to produce the desired effect of reducing and maintaining cooler water temperatures on the Snake River. Water releases from Dworshak Dam for flow augmentation/temperature moderations began on July 2 several days after the Dworshak reservoir reached full with a forebay elevation was at 1599.9 ft on June 23. The Corps achieved the RPA Action 4 objective of refilling Dworshak reservoir to 1600 ft. Water releases continued through September 16, when the forebay elevation of 1520.0 ft was reached. The Corps achieved the RPA Action 4 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. The Walla Walla District performs CE-QUAL-W2 temperature modeling

Appendix I provide a full discussion of Dworshak releases for flow augmentation and temperature control and how these operations fulfilled the 2008 BiOp requirements.

6.2 Water temperature modeling

The 2008 BiOp RPA Action 15 calls for "continued development and use of the CE-QUAL-W2 temperature model for estimating river temperatures from Dworshak Dam on the Clearwater and Upper Snake River near the confluence with the Grand Ronde River (USGS Anatone gage) through the lower Snake River (all four Corps lower Snake River

projects) to assist in real-time decision making for Dworshak Dam operations". As Appendix I, on Dworshak operations documents, the CE-QUAL-W2 model was used 11 times during the summer temperature augmentation for the lower Snake River. This model enabled the Corps, in conjunction with TMT, to determine the best discharge sequences from Dworshak Dam to meet the temperature targets in the Lower Snake. The model results provided information to manage the discharge from Dworshak Dam more effectively during the augmentation season. The near real-time decision capability allows for more flexibility to meet the RPA Action 15 requirement associated with temperature modeling. The CE-QUAL-W2 modeling performed during the 2009 Dworshak Dam summer operations fulfilled the RPA Action 15 modeling requirement.

The Corps' Walla Walla District is currently working to further enhance the CE-QUAL-W2 model by calibrating to a larger set of observed data as well as upgrading to a new version of the model. The scope for this work is still being developed. These improvements should allow the model to be utilized more as a continuous simulation model, which will allow for better in-season decisions.

The 2008 BiOp RPA Action 15 also calls for the Action Agencies to "expand water temperature modeling capabilities to include the Columbia River from Grande Coulee to Bonneville dams to better assess the effect of operations or flow depletions on summer temperatures" (RPA-15). In section 14.5.2 Terms & Conditions Related to Improving Juvenile & Adult Passage of the 2008 BiOp it discusses water temperature modeling and says,

> "The FCRPS Action Agencies shall continue to refine a water quality model that addresses Columbia and Snake mainstem river temperature monitoring and meteorological data. The model shall initially be applied to river management decisions for the lower Snake River. The FCRPS Action Agencies will continue to develop an expanded data gathering network and strategy compatible with the model requirements. Continued refinement or the creation of improved water quality models will reduce take by providing managers better temperature assessment capabilities which should result in improved in-season management decision-making (flow releases from water storage projects, dam operations, etc.)."

This section of the 2008 BiOp suggests that NOAA Fisheries are encouraging the flexibility to select the best water temperature model for modeling the Columbia and Snake rivers. Currently, the Corps hasn't modified the CE-QUAL-W2 to model the Columbia River from Grande Coulee to Bonneville dams, but is working toward obtaining funding to pursue it in the future.

6.3 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 12 and 13.

TABLE 12
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 of twenty-two (22) degrees C or less with a maximum daily average of no greater than nineteen (19) degrees C."

TABLE 13
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 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 0.3 C (0.5 F) due to a single source or 1.1° C (2.0 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);

Part 7 Fish Passage Summary

7.1 Biological Monitoring

The spill cap levels in the FOP, consistent with state and tribal water quality variances 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 monitoring of juvenile salmonids in 2009 for gas bubble trauma (GBT) was conducted at 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.

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 of the sampling program was to sample 100 salmonids of the most prevalent species (limited to Chinook and steelhead) during each day of sampling at each site, with the proportion of each species sampled dependent upon their prevalence at the time of sampling. Yearling Chinook and steelhead were sampled through the spring at all the sampling sites. Once subyearling Chinook predominated in the smolt collections, the program shifted from sampling yearling Chinook and steelhead to sampling subyearling Chinook through the end of August. 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, 12,935 juvenile salmonids were examined for GBT between April and August of 2008 (Table M2 of Appendix M). Fin signs were found in 37, or 0.29%, of the fish sampled at all sites (see Table 3 of Appendix M). All fish examined and determined to have signs of GBT exhibited the less severe fin signs of rank 1, where less than 5% of a fin area was covered with bubbles. Table M4 of Appendix M compares the 2009 estimates of the overall percentage of fish with signs of GBT to past years' estimates.

The action criteria for GBT is established as 15% of fish showing any signs of GBT, or 5% of the fish sampled showing signs greater than rank 1. In 2009 there were no fish detected with signs of GBT at Lower Granite and Lower Monumental dams and very few fish with signs of GBT were observed at Little Goose and McNary Dam (See Figure M-3 and Figure M-4 in Appendix M). A few more fish were observed at Rock Island Dam (See Figure M-5 in Appendix M), however, this occurrence happens every year and is likely a function of holding fish in shallow water for a time period before sampling. The site where the most fish were observed with signs of GBT in the Federal Columbia River Power System was at Bonneville Dam (See Figure M-6 in Appendix M). The percentage of fish showing signs of GBT peaked in early June, but only a few percent of the sample were affected and the percentage did not approach the action criteria of 15%.

The Biological Opinion 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. The GBT criteria were never exceeded in the Snake or Columbia rivers in 2009, with the highest daily

observation in 2009 being 4%. This was observed at Rock Island Dam on April 23, 2009, the first day of sampling.

GBT sampling was successfully accomplished for the 2009 migration season. In summary very few fish were detected with signs of GBT in 2009. Limited incidence was observed in the Snake River with most signs of GBT observed in the lower Columbia River. However, the signs observed were of the lowest designation and were only present in a small portion of the population. The observations from the GBT program reflect the generally lower TDG measured in the system this year.