US Army Corps of Engineers®

Northwestern Division

2010 DISSOLVED GAS AND WATER TEMPERATURE REPORT

COLUMBIA RIVER BASIN

McNary Tailwater TDG Monitoring Site

Columbia Basin Water Management Division
Reservoir Control Center
Water Quality Team

December 2010

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

Including Material Provided by:
Portland District – U.S. Geological Survey (Portland Office)
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2010 TOTAL DISSOLVED GAS AND WATER TEMPERATURE REPORT COLUMBIA RIVER BASIN

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List of Acronyms

The following acronyms are used throughout this report.

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
NWRFC	Northwest River Forecast Center
NWF	National Wildlife Federation
NWPC	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
USFWS	United States Fish and Wildlife Service
Reclamation	United States Bureau of Reclamation
USGS	United States Geologic Service
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 used throughout this report.

FCRPS Action Agencies: The three federal agencies responsible for the operation of the FCRPS are the Corps, Reclamation, and BPA.

Involuntary Spill: Spill that resulted primarily from dam 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 nights 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 dam facilities.

Lack of Load: The condition where a lack of customer need for power results in a lack of market for electricity generated.

Spill cap: Spill caps are the maximum spill that can occur and the High 12 hour percent TDG average will remain within the state water quality standards of 115 percent in the forebay or 120 percent in the tailwater.

TDG Instance: Instances are times when TDG levels exceeded state standards and applicable waivers and rule adjustments.

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 (Reclamation), NOAA Fisheries, U.S. Fish

and Wildlife Service (USFWS), Corps, three states (Idaho, 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 dam 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, and may be limited by in-river flow.

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 2010 and covers the lower Columbia and Snake River dams located in Washington, Idaho and Oregon. This report was developed to meet the Corps' water quality program responsibilities related to the Oregon Total Dissolved Gas (TDG) waiver, the Washington TDG rule adjustment, the 2010 Fish Operations Plans, the NMFS 2008 FCRPS Biological Opinion and 2010 NMFS Supplemental FCRPS Biological Opinion (2010 Supplemental BiOp) and the 2002 and 2003 TDG Total Maximum Daily Loads (TMDLs) for the lower Columbia and lower Snake rivers.

This document satisfies the Corps' reporting requirements associated with the Oregon TDG waiver, Washington TDG rule adjustment, and supports other efforts and reporting activities associated with the 2010 Fish Operations Plans, the 2010 Supplemental BiOp, and the TDG TMDLs. This report provides information requested in the Oregon TDG waiver and Washington rule adjustment including 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 dam, 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 Snake rivers TDG TMDL documents. This information is used by the states in processing waivers or rule adjustments to the WQS for TDG. This report includes documentation on the status of meeting the TDG monitoring program and the 2010 Supplemental BiOp, 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.

This report focuses on the spill and water quality monitoring of TDG and temperature at the 10 Corps Columbia River basin dams located in Washington, Idaho and Oregon (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. The following is a list of the appendices which provide background and documentation for this report:

- Appendix A - General overview of the monitoring system with information on the fixed monitoring stations (FMS).
- Appendix B - Dissolved Gas Monitoring Plan of Action for 2010.
- Appendix C - Fish Operations Plans (FOP) that was used as the guideline for 2010 spill season.
- Appendix D - Reports on the FOP spill volumes for 2010.

- Appendix E - 2010 monthly 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 - Summary tables of TDG levels and instances and instance types of when TDG levels exceed state WQS.
- Appendix G - Detailed evaluation of the SYSTDG model performance during the 2010 spill season.
- Appendix H - Hourly water temperature data graphs.
- Appendix I - Dworshak summer operations.
- Appendix J - Quality Assurance/Quality Control (QA/QC) review for TDG and temperature monitoring gauges at Lower Granite, Little Goose, Lower Monumental, Ice Harbor, and McNary dams.
- Appendix K - QA/QC review for TDG and temperature monitoring gauges at John Day, The Dalles, Bonneville, and the Warrendale and Camas/Washougal sites.
- Appendix L - QA/QC review for TDG and temperature monitoring gauges at Chief Joseph dam.
- Appendix M - Fish Passage Center report entitled Gas Bubble Trauma Monitoring and Data Reporting.
- Appendix N - 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 performs the following functions:

1. Monitor spill in relation to the 2010 FOP spill objectives;
2. Documents the status of Corps actions on 2010 Supplemental BiOp water quality objectives;
3. Monitor dam performance in relation to WQS; and
4. Provide water quality data for anadromous fish passage at Columbia/Snake mainstem dams.

Voluntary spill is monitored at Grand Coulee and the Corps dams listed in Section 1.0. In coordination with the Bureau of Reclamation (Reclamation), the Corps sets spill caps for Grand Coulee Dam. Dam operating data and water quality monitoring data are reviewed daily as part of the process of setting daily spill caps to maintain TDG levels within the 115 and 120 percent TDG criteria. Instances when TDG and temperature criteria are exceeded, relative to state standards and applicable waivers and rule adjustments, 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, Oregon and Washington. TDG may be influenced by dam 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 (RCC) is part of a larger interagency water quality monitoring system operated by the Corps that also includes the Reclamation 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 Opinions

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 dams 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 eight lower Columbia and Snake rivers mainstem dams up to a level of 120 percent TDG where state rule adjustments 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 1992 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

USFWS 2000 BiOp
According to the USFWS 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.

NMFS 2008 and 2010 Supplemental FCRPS BiOps
The NMFS 2008 FCRPS BiOp (2008 BiOp) was finalized on May 5, 2008 and after a voluntary remand NMFS issued the 2010 Supplemental FCRPS BiOp (2010 Supplemental BiOp) on June 11, 2010. For the 2010 fish migration season, the Court ordered the Federal agencies to adopt 2010 FOP operations based on the operations from the previous year. The Federal agencies produced the 2010 Spring FOP, followed by a 2010 Summer FOP. The 2010 Spring and Summer FOPs are provided in Appendix C.

The Supplemental FCRPS BiOp may be found at the following website:
http://www.nwr.noaa.gov/Salmon-Hydropower/Columbia-Snake-Basin/final-BOs.cfm

1.1.4 TDG Standards

The following is a list of the TDG water quality standards as currently approved by the Colville tribes and the states of Idaho, Oregon, and Washington.

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 percent of saturation at any point of sample collection.

State of Idaho:
IDAPA 58.01.02-250- 01(b): The total concentration of dissolved gas not exceeding one hundred ten percent (110%) of saturation at atmospheric pressure at the point of sample collection.

State of Oregon:
OAR 340-041-0031:

- 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 streamflow 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 percent 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 percent of saturation.

OAR 340-041-104(3): Total Dissolved Gas. The Commission may modify the total dissolved gas criteria in the Columbia River for the purpose of allowing increased spill for salmonid migration. The Commission must find that:

- (a) Failure to act would result in greater harm to salmonid stock survival through in-river migration than would occur by increased spill;
- (b) The modified total dissolved gas criteria associated with the increased spill provides a reasonable balance of the risk of impairment due to elevated total dissolved gas to both resident biological communities and other migrating fish and to migrating adult and juvenile salmonids when compared to other options for in-river migration of salmon;
- (c) Adequate data will exist to determine compliance with the standards; and
- (d) Biological monitoring is occurring to document that the migratory salmonid and resident biological communities are being protected;
- (e) The Commission will give public notice and notify all known interested parties and will make provision for opportunity to be heard and comment on the evidence presented by others, except that the Director may modify the total dissolved gas criteria for emergencies for a period not exceeding 48 hours;
- (f) The Commission may, at its discretion, consider alternative modes of migration.

The Corps received a TDG waiver on June 24, 2009 from the State of Oregon effective for the 2010-2014 spill seasons. The Environmental Quality Commission approved a modification to the 110 percent total dissolved gas water quality standard for voluntary fish passage spill at McNary, John Day, The Dalles and Bonneville dams on the lower Columbia River, subject to the nine conditions. Two operational conditions are highlighted for the purposes of this report:

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

2. (iv) Spill must be reduced when instantaneous TDG levels exceed 125 percent of saturation for any 2 hours during the 12 highest hourly measurements per calendar day in the tailraces of McNary, John Day, The Dalles, and Bonneville dams monitoring stations.

State of Washington:

WAC 173-201A-200(1)(f): Aquatic life total dissolved gas criteria. TDG is measured in percent saturation. Table 200 (1)(f) lists the maximum TDG criteria for each of the aquatic life use categories.

TABLE 200 (1)(f)
Aquatic Life Total Dissolved Gas Criteria in Fresh Water

Category	Percent Saturation
Char Spawning and Rearing	Total dissolved gas shall not exceed 110 percent of saturation at any point of sample collection.
Core Summer Salmonid Habitat	Same as above.
Salmonid Spawning, Rearing, and Migration	Same as above.
Salmonid Rearing and Migration Only	Same as above.
Non-anadromous Interior Redband Trout	Same as above.
Indigenous Warm Water Species	Same as above.

(i) The water quality criteria established in this chapter for TDG shall not apply when the stream flow exceeds the seven-day, ten-year frequency flood.

(ii) The TDG criteria may be adjusted to aid fish passage over hydroelectric dams when consistent with a department approved gas abatement plan. This plan must be accompanied by fisheries management and physical and biological monitoring plans. The elevated TDG levels are intended to allow increased fish passage without causing more harm to fish populations than caused by turbine fish passage. The following special fish passage exemptions for the Snake and Columbia rivers apply when spilling water at dams is necessary to aid fish passage:

• TDG must not exceed an average of 115 percent as measured in the forebays of the next downstream dams and must not exceed an average of 120 percent as measured in the tailraces of each dam (these averages are measured as an average of the twelve highest consecutive hourly readings in any one day, relative to atmospheric pressure); and

• A maximum TDG one hour average of 125 percent must not be exceeded during spillage for fish passage.

On June 30, 2010, the State of Washington approved the gas abatement plan, submitted March 22, 2010. Two conditions are highlighted for the purpose of this report:

1) This approval shall extend through the end of February 2015 and apply to Corps dams on the Columbia and Snake rivers in Washington State.
2) This approval allows spill to increase the dissolved gas levels above 110 percent of saturation to aid fish passage, but not to exceed 125 percent of saturate as a one-

hour average. Gas saturation may not exceed 120 percent in the tailrace and 115 percent in the forebay of the next downstream dam as measured by the highest 12-hour, consecutively- averaged value in any one day.

1.1.5 TDG Waiver History

The following sections provide the history of the Oregon TDG waivers and the Washington rule adjustments.

State of Oregon

The Corps took appropriate actions for attaining a TDG waiver from the State of Oregon for the 2002-2010 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 waiver for the 2002 spill season. The Oregon Environmental Quality Commission approved a waiver 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 waiver 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 waiver. 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 waiver to the Oregon TDG standard for the period 2008 through 2012 with the same conditions as specified in the previous waiver. The Oregon Environmental Quality Commission met on June 21, 2007 and approved a 2-year waiver for the 2008-2009 spill seasons.

On January 9, 2009, the Corps again submitted information to ODEQ for use in processing a TDG waiver. The Oregon Environmental Quality Commission met on June 24, 2009 and approved a 5-year waiver for the 2010-2014 spill seasons.

State of Washington:

In 1997, the State of Washington modified its WQS TDG rule to allow for adjusted TDG criteria when spilling water over dams to aid fish passage. This new rule (WAC 173-201A-060(4)(b)), was subject to approval of a gas abatement plan, and submission of a fisheries management plan, and plans for physical and biological monitoring. In 2003, this rule was moved to WAC 173-201A-200(1)(f).

NOAA Fisheries submitted the first federal request for a TDG rule adjustment from Washington Department of Ecology (WDOE) 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 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 a 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 a 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 gas abatement plan. On February 8, 2008, the WDOE approved the gas abatement plan effective through February 2010.

On January 9, 2009, the Corps again submitted information to WDOE for use in processing the TDG criteria adjustment. On March 22, the Corps submitted additional information to WDOE updating the gas abatement plan as requested in the February 8, 2008 letter. On March 29, 2010, WDOE provided an extension of the TDG criteria adjustment approval until June 30, 2010. Then on June 30, 2010, WDOE approved the gas abatement plan through February 2015.

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 "TMDL for Lower Columbia River Total Dissolved Gas (Sept 2002)," and the "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 also 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. For more detailed information on the TDG monitoring studies

that were conducted in 2010 in support of the TDG TMDL and updating of SYSTDG, see Part 4.3.

1.1.7 Operating Guidelines

The Corp's RCC Water Quality Unit is responsible for monitoring the TDG and water temperature conditions in the forebays and the tailwaters of the lower Columbia and Snake River dams, and selected river sites. The Corps' District water quality staff operates and maintains the water quality gauges at the FMSs. 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 WQS (including waivers or rule adjustments).

Both Oregon and Washington changed their WQS during the last three years which would affect how TDG instances are calculated and which TDG gauges are used for spill management. The changes to the state WQS were not implemented in 2010 because of the NOAA Fisheries 2008 Biological Opinion litigation. The Corps instead operated consistent with the U.S. District Court of Oregon orders, in which the previous TDG monitoring system with forebay gauges and the method for calculating the 12 hour average used in 2007 continued through 2010.

During the 2010 spill season, adjustments were made to the upstream dam spill levels to maintain the average of the 12 highest values in 24 hours in dam forebays at less than 115 percent TDG and the average of the 12 highest values in 24 hours in dam tailwaters at less than 120 percent. When adjustments to spill caps are made, the evaluation includes information regarding the water volume, water elevation (where applicable), dam powerhouse and spillway characteristics (where applicable), current and future special operations, current TDG levels in the forebays and tailwaters, water temperatures, and short- and long-term weather forecasts.

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, WDOE implemented a change in their method of calculating percent TDG to use 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 called the "Washington method". In 2008, as a result of the Adaptive Management Team meetings, Oregon determined that 115 percent TDG standard and forebay gauges are not needed to assess acceptable TDG levels in the lower Columbia River. As a result, ODEQ revised their method of calculating the "daily percent TDG" to an average of the 12 highest hourly readings in a given day for tailwater gauges only. For the purposes of this report, this method is called the Oregon method of calculating the 12-hour TDG. Part 5 of this report provides detailed information

on the TDG instances using the Oregon/Washington and Washington methods with an evaluation and comparison of these two methods.

Part 2 Program Operating Conditions

2.1. Water Year Runoff Conditions

Part 2 provides an overview of the water year run off and reservoir operations, which includes a description of the weather; flood control, total river flows; 7Q10 flows and the Chief Joseph and Grand Coulee spill shift.

2.1.1 Weather

The 2010 water year, which began in October 2009, was near average in precipitation as shown in Table 1. The cumulative precipitation as reported by the Northwest River Forecast Center (NWRFC) for water year 2010 was 96 percent of average (1971 to 2000) in the Columbia River above Grand Coulee, 96 percent of normal in the Snake River above Ice Harbor Dam, and 103 percent of normal in the Columbia River above The Dalles, Oregon.

October 2009 transitioned to weather systems that brought moderate to heavy rain and snow to the Columbia Basin. An early season Arctic front pulled the colder air over the rest of the region as the month progressed. A warmer weather system in mid to late month replaced this cold system, and delivered significant rainfall to British Columbia and the northern part of the Basin.

November 2009 began with high pressure and drier weather, but this pattern gave way to a series of fronts by the middle of the month and persisted for the rest of the month. These were quick-moving weather systems, so precipitation was, for the most part, below normal. November temperatures were on average very mild.

In early December 2009 arctic air found its way south which is fairly typical in El Niño winters in the Northwest and Columbia Basin. As a result, the month began drier than normal, with a slowly developing wetter segment mid to late month, as the split flow pattern tried to consolidate, and the air mass warmed mainly over the U.S. sector. The month closed on a transitional note, from cold and dry to wetter and milder, as El Niño conditions prevailed leading into the start of 2010. The El Niño event reached moderate status in late December, as measured according to equatorial Pacific sea surface temperatures.

January 2010 began wetter than normal. A series of two strong storm systems brought heavy rain and snow to the region to open up the New Year. This pattern lasted until about midpoint into the second week of the month, when the split flow pattern resumed.

The El Niño split flow weather pattern continued into February, with weather systems diverting north and south of the Columbia Basin. Therefore, warmer- and drier-than-normal weather ruled even though the weather pattern became more active, with storms

later in the month. California received the bulk of the rain and snow, while the polar branch of the storm track continued to play tag with the Upper Columbia Basin, which supplies two thirds of the stream flow at The Dalles.

As March arrived, the El Niño event that peaked in early winter was showing signs of weakening. A series of strong low pressure systems delivered moderate to heavy precipitation, especially during the first half of March. There was a break about mid-month, when warm weather occurred, and then storminess resumed late month. The late March precipitation increase carried forward into April.

In April, there were increased precipitation and cooler temperatures typical of an El Niño spring. April had a cold first half and much warmer last half of the month.

More wet cold weather ensued in May, with record rainfall, and mountain snowfall. The weather pattern forced a major turnaround in the streamflow profile, from drought conditions to flooding.

June continued the wet and cold weather pattern, and La Niña conditions quickly emerged in the equatorial Pacific. Low pressure systems continued across the Columbia Basin for June and brought a period of moderate rain west of the Cascades. The low pressure systems east of the Cascades brought showers, and thunderstorms, some of which were severe. High pressure pushed in from the North Pacific toward the end of the month, and thus the weather pattern dried.

July arrived with typical summer conditions. The basin dried out steadily, as the La Niña summer weather pattern transpired with cooler than normal conditions.

August continued to be cool, as onshore flow persisted, and only weak upper level high pressure reaching the area. The first part of August was dry and pleasant for much of the Northwest with diurnal convection over the northern Rockies. A low pressure system developed over British Columbia and moved south into Idaho and Montana by the middle of the second week bringing strong thunderstorms to the northern Rockies. At the end of the second week a strong high pressure ridge built over the coast and helped to break many high temperature records in this region. This ridge began to breakdown by the beginning of the third week with a wetter, cooler pattern moving in over the Northwest. This pattern continued into the fourth week of August with many areas in the Rockies experiencing freezing temperatures overnight.

At the beginning of September, the Columbia Basin and areas west of the Cascade Mountains saw dry and warm conditions as high pressure resided over the region. An active jet stream moved into the region and continued to bring disturbances over the Northwest US and southern British Columbia for the next few weeks. Most areas saw periods of showers through much of the month. High pressure returned at the end of the month bringing warmer and drier conditions back to the region.

TABLE 1
Columbia River Basin Percent Precipitation
WY 2010

Location	Columbia River above Grand Coulee	Snake River above Ice Harbor	Columbia River above The Dalles
October 2009	164	154	170
November 2009	64	49	65
December 2009	57	67	85
January 2010	79	96	87
February 2010	34	45	48
March 2010	85	84	82
April 2010	109	140	130
May 2010	95	106	115
June 2010	154	201	177
July 2010	60	43	52
August 2010	92	94	87
September 2010	162	71	137
WY Average	96	96	103

Note: Percent precipitation as percentage of the 1971-2000 average.

2.1.2 Streamflow

The NWRFC April 1, 2010 forecast of January through July runoff for the Columbia River above The Dalles was 69.7 Maf, and the actual observed runoff was 84.7 Maf. For the Columbia River above The Dalles, the average January-July runoff volume for the 1971-2000 period is 107.3 Maf.

The WY 2010 daily average unregulated stream flow in the Basin above The Dalles was below normal and approximately 5.9 percent lower than last year's average flow, which was also below normal. Table 2 provides the unregulated flows for each month at Grand Coulee and The Dalles. The average monthly unregulated inflows during spring runoff were highest in June 2010; 104 percent of average at The Dalles.

The WY 2010 total runoff volume at The Dalles was 110.1Maf, which is 80 percent of the 1971-2000 average. The peak-unregulated discharge for the Columbia River at The Dalles was 550.1 kcfs on June 7, 2010. The 2009-2010 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 2. These flows have been adjusted to exclude the effects of regulation provided by storage reservoirs.

TABLE 2
Columbia River Flow in 2009-2010

Time Period	At Grand Coulee		At The Dalles	
	Unregulated Flow, cfs	% of Average	Unregulated Flow, cfs	% of Average
October 2009	32,478	72	68,778	83
November 2009	35,040	72	78,381	83
December 2009	25,469	59	64,045	65
January 2010	30,575	73	79,187	77
February 2010	28,864	61	74,437	61
March 2010	38,252	61	86,603	56
April 2010	87,238	71	163,669	69
May 2010	169,742	64	287,652	66
June 2010	293,274	95	488,050	104
July 2010	156,731	82	226,436	88
August 2010	81,236	78	114,186	83
September 2010	62,500	101	93,725	100
WY Average	86,783	74	152,096	78

2.1.3 Reservoir Operation

The following overview of reservoir operations includes a description of flood control, total river flows and the 7Q10 flows.

2.1.3.1 General

The WY 2010 water year began with Grand Coulee storage at 94 percent full. The water supply was below average across the Columbia Basin, and the shape of the runoff included one modest peak starting the first week of June and continuing through the end of June. The actual runoff for the overall Columbia Basin as measured at The Dalles for the April through August 2010 was 83 percent of normal.

The general operations included operating U.S. storage reservoirs to attempt to reach the upper rule curve elevation on or about April 10, 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 Priest Rapids and McNary Dam, but not at Lower Granite Dam. Spring and summer spill for fish passage was executed at the lower Columbia River and lower Snake River dams. The lower Snake River dams were operated within one foot of their minimum operating pools (MOP) for the migration season. On August 5 the Corps modified the MOP operating range at Little Goose due to navigation safety concerns. The normal MOP range for Little Goose is 633.0 to 634.0 feet, but during low flow conditions (approximately 32 kcfs or lower as a daily average), gauge readings indicated there was insufficient depth over the navigation sill for safe transit at the entrance to the Lower Granite navigation lock. In order to ensure safe navigation under these flow conditions, the Corps revised the operating range at Little Goose Dam to 633.5 to 634.5 feet for the remainder of the spill season (August 31). This operation was coordinated with TMT and no concerns were raised by TMT members.

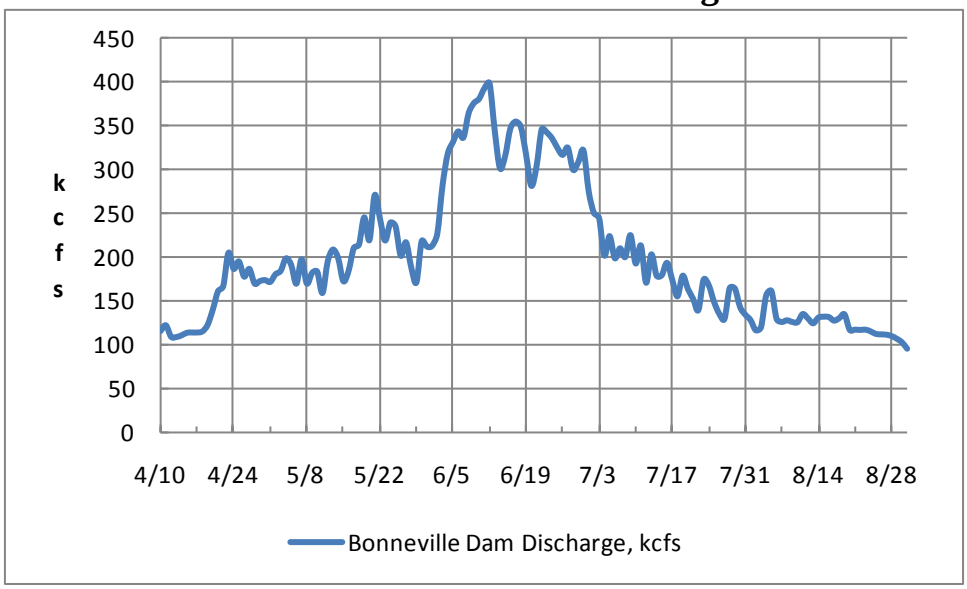
2.1.3.2 Flood Control

The NWRFC 2010 water supply forecasts were below normal across the Columbia River Basin. Inflow forecasts and reservoir regulation modeling were performed weekly throughout the winter and spring. The FCRPS dams were operated for flood control 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 550 kcfs on June 7, 2010, and a regulated peak flow of 391 kcfs occurred on June 11, 2010 as measured at the USGS gauge at The Dalles, Oregon. The unregulated peak stage at Vancouver, Washington, was calculated to be 19.2 feet on June 9, 2010, and the highest observed stage was 14.6 feet on June 12, 2010.

2.1.3.3 Total River Flows

Daily average total river flows on the lower Columbia River, as measured at Bonneville Dam, from April 10 through August 31 ranged from 97 kcfs to 398 kcfs, averaging 199 kcfs (Figure 1). Daily average flow remained above 300 kcfs, the 2010 involuntary spill threshold for the lower Columbia River, from June 4 through June 30 (with the exception of June 14 with 281 kcfs), with a peak of 398 kcfs on June 12. Flows began to taper off in early July, dropping below 200 kcfs on July 14, and continued a steady recession until the end of August when flows reached 97 kcfs.

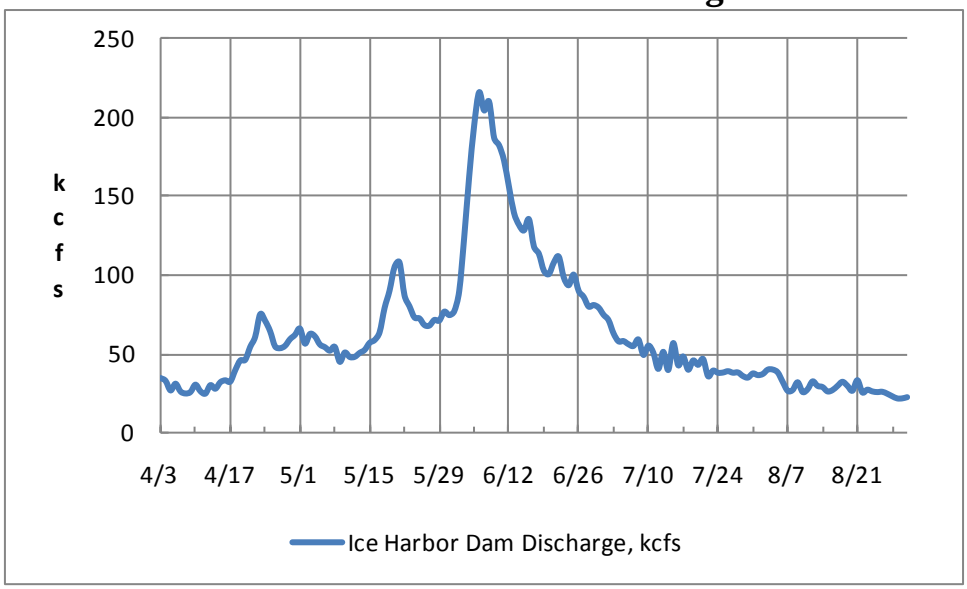
FIGURE 1
2010 Bonneville Dam Discharge



On the lower Snake River, as measured at Ice Harbor Dam, total river daily average flow from April 1 through August 31 ranged from 22 to 216 kcfs averaging 63 kcfs (Figure 2) Daily average flow rose above 120 kcfs, the 2010 involuntary spill threshold for the lower Snake River, from June 3 through June 16, with a peak of 216 kcfs on June 6. It was during this period that involuntary spill occurred at several lower Snake River dams. Total

river flows continued to recede on the lower Snake River through July and August, until total river flows reached 24 kcfs on August 28.

FIGURE 2
2010 Ice Harbor Dam Discharge



2.1.3.4 7Q10 Flow

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 States consider these occurrences to be of a natural origin and occur relatively infrequently. The 7Q10 daily average flows for the various dams are shown on Table 3.

TABLE 3
7Q10 Flows in kcfs

Project	7Q10 Flows	Powerhouse Capacity Within 1% Efficiency	Powerhouse Capacity Without One Unit	The Rate of Spill at 7Q10 Flows[1]
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
CHJ	241	N/A	211	30
DWR	N/A	N/A	13	N/A

1. Assuming no generation limitation due to lack of load.

The 7Q10 flow levels were calculated based on the flow that the FCRPS dams can discharge with all turbines except one operating. The 7Q10 flows were established through coordination with Oregon and Washington. Peak discharges in 2010 at all dams in Table 3 were below the 7Q10.

Part 3 Water Quality Monitoring

3.1 Fixed Monitoring Stations

TDG and water temperature are monitored throughout the Columbia River Basin via the FMS gauges. There are a total of 42 FMSs in the U.S. portion of the Columbia River Basin and the Corps operates 28 of these 42 FMSs. Reclamation, and the Chelan and Grant County PUDs each operate four stations. Two stations are operated by the Douglas County PUD. The Corps' Portland, Seattle, and Walla Walla Districts operate and maintain the FMSs in the Columbia and lower Snake River basins. Portland District is responsible for eight FMSs on the lower Columbia River from John Day Dam to Camas-Washougal. The Seattle District is responsible for two FMSs in the upper Columbia Basin at Chief Joseph. Walla Walla District is responsible for 15 FMSs in the lower Snake River and Clearwater River basins, and at McNary Dam on the Columbia River. Appendix A contains detailed information on the Corps owned FMS system and a map of their locations.

3.2 Monitoring Plan of Action

The Corps prepares an annual Dissolved Gas Monitoring Plan of Action which is a supporting document which summarizes the Corps' roles and responsibilities with dissolved gas and temperature monitoring and identifies channels of communications with other cooperating agencies and interested parties. The monitoring Plan of Action stipulates what to measure, how and when to take the measurements, and how to analyze and interpret the resulting data. The Plan of Action 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 monitoring Plan of Action is Appendix B of this report.

3.3 Changes in the FMS

There were no noteworthy changes to the Corps TDG FMS system during 2010.

3.4 Malfunctioning Gauge Occurrences

During 2010 there were five occurrences affecting 7 days where a FMS gauge malfunctioned due to various reasons. The data from these FMS gauges showed elevated TDG levels ranging from approximately 113.0 percent to 148.8 percent and are noted as a Type 2a instance in Tables F-2, F-3A and F-3B (Appendix F) to indicate when a TDG instance from a malfunctioning gauge occurred and appeared as part of the real-time operational review. Table F-2 is based on raw data and is populated during real-time operations. Tables F-4 through F-6 do not include the malfunctioning gauge data since these tables provide statistical information on hourly TDG levels.

3.5 QA/QC on FMS

The 2010 Supplemental BiOp, RPA Action 15, calls for "real-time monitoring and reporting of TDG and temperatures measured at fixed monitoring sites". The Corps' Districts operate the FMS according to the monitoring Plan of Action and prepare annual performance reports for the FMS operations included as Appendices J, K and L. Highlights from these reports are provided below.

3.5.1 Walla Walla District QA/QC

The Walla Walla District is responsible for maintaining and operating the forebay and tailwater gauges at the Dworshak, Lower Granite, Little Goose, Lower Monumental, Ice Harbor and McNary dams. This work is performed through a contract with the Kennewick office of the USGS. The highlights of the Walla Walla District QA/QC report are:

- Operated fifteen FMSs (nine seasonal and six year-round) for TDG, barometric pressure, and temperature as part of their 2010 water-quality program. Table J-7 (Appendix J) provides individual FMS data completeness information. These results exceed the 95 percent dada completeness goal. Table J-9 provides the causes for missing data.

- Data completeness for barometric pressure, TDG, and water temperature data were 99.7, 99.2, and 99.6 percent respectively. This data were received in real-time and passed provisional QA/QC review. Percent completeness subsequently increased to 99.8, 99.5, and 99.8 percent for barometric pressure, TDG, and temperature, respectively after the data was compared to the information from the electronic data loggers.

- Data Collection Platform (DCP) failure caused 32.3 percent of the invalid/missing provisional real-time barometric pressure and TDG data followed by 10.5 percent and 20.1 percent attributable to vandalism and defective Hydrolab sondes, respectively. When the data was corrected with information from the electronic data loggers, 34.4 percent of the aberrant data was due to vandalism while 26.4 percent was attributed to DCP failure.

- The sonde pre-deployment check had calculated median TDG and temperature differences of -0.2 mm Hg and -0.01°C, respectively.

- The sonde post-deployment QA/QC checks also displayed favorable results. The differences between the laboratory barometric pressure and that recorded by the sondes averaged 0.01 mm Hg. The checks using barometric pressure +100 mm Hg had a calculated mean of -0.01 percent. Temperature post calibration checks resulted in a calculated mean of -0.03°C

- The Dworshak tailwater deployment pipe was extended approximately 30 feet to improve water circulation around the sonde during low flow conditions. Also, the deployment pipes at Pasco, Peck, Lewiston, and Anatone were purged with compressed air to remove silt accumulation.

- All 15 FMSs were 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 2009 and March 2010.

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

3.5.2 Portland District QA/QC

Portland District is responsible for maintaining and operating the forebay and tailwater gauges 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 the 2010 water year, an average of 99.7 percent of the TDG data were received in real-time by the USGS satellite downlink and were within 1 percent 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 98.4 percent to 100.0 percent complete. See Table 2 in Appendix K for individual gauge data completeness information. These results exceed the data quality criteria for data completeness. Table 3 in Appendix K provides the causes for missing data.

- The TDG sensors were removed from the field after 3 or 4 weeks of deployment and calibrated in the laboratory.

- All but 1 of the 85 in-situ field checks of total-dissolved-gas sensors with a secondary standard were within ±1.0 percent saturation after 3 to 4 weeks of deployment in the river.

- The eight FMSs were calibrated every 3 weeks, except from October 2009 through March 2010, when they were calibrated at 4-week intervals.

- All 88 of the field checks of barometric pressure were within ±1 mm Hg 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 gauges can be found in Appendix K.

3.5.3 Seattle District QA/QC

Seattle District is responsible for maintaining and operating the forebay and tailwater gauges at Chief Joseph Dam. The gauge 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 2010, an average of 100 percent of the TDG data were received in real-time from the DCP by a radio transmitter. See Table 2 (Appendix L) for individual gauge data completeness information. These results exceed the data quality criteria for data completeness.

- There was no missing data for the two stations in 2010 and no data were rejected.

- Laboratory calibration data were good and within 0.1^{o}C for temperature and 1 percent saturation for TDG. Field calibration data were good and generally within 5 mm Hg of the secondary standard barometer, 0.2ºC of the secondary standard thermometer, and 10 mm Hg saturation of the secondary standard TDG instrument.

- Field calibration data for temperature were good and generally within 0.2ºC of the secondary standard thermometer.

- Field calibration data for TDG were generally within 10 mm Hg of the secondary standard TDG instrument.

- Field calibration data for barometric pressure were generally within 5 mm Hg of the secondary standard.

- The two FMS were calibrated every 2 to 4 weeks. The FMS were not operating during the October 2009 through March 2010 time period.

The full QA/QC report on the Seattle District gauges 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 provided voluntary spill for fish passage consistent with the 2008 and 2010 Supplemental BiOps and the 2010 FOPs, which include voluntary spill for fish passage. Part 4 provides detailed information on the implementation of the spill program described in the 2010 FOPs, as well as spill for other reasons (e.g. lack of powerhouse capacity, transmission constraints, etc.).

4.1.1 Fish Operations Plans

The 2010 Spring and 2010 Summer FOPs provided in Appendix C describe specific fish operations implemented in 2010 and are summarized in Table 4.

TABLE 4
2010 FOPs Spill Operations

Project	Planning Dates [A & B]	Time	Spill Amount
Lower Granite	April 3 - June 20	24 hours per day	20 kcfs
Lower Granite	June 21-August 31	24 hours per day	18 kcfs
Little Goose	April 3 - August 31	24 hours per day	To the spill cap up to 30% of project outflow
Lower Monumental	April 3 - June 20	24 hours per day	To the spill cap
Lower Monumental	June 21-August 31	24 hours per day	17 kcfs
Ice Harbor	April 3 - April 27	0500-1800	45 kcfs during the day
Ice Harbor	April 3 - April 27	1800-0500	To the spill cap
Ice Harbor	April 28 - July 12	24 hours per day	Alternating between to the spill cap up to 30% vs. 45 kcfs during the day/spill cap at night
Ice Harbor	July 13 - August 31	0500-1800	45 kcfs during the day
Ice Harbor	July 13 - August 31	1800-0500	To the spill cap
McNary	April 10 - June 19	24 hours per day	To the spill cap up to 40% of project flow
McNary	June 20-August 31	24 hours per day	To the spill cap up to 50% of project flow
John Day	April 10 - July 20	24 hours per day	To the spill cap up to 30% vs. 40% of project outflow
John Day	July 21 - August 31	24 hours per day	To the spill cap up to 30% project outflow
John Day	April 10 - August 31	24 hours per day	Minimum spill is 25% of project outflow
The Dalles	April 10 - August 31	24 hours per day	To the spill cap or 40% of project outflow
Bonneville	April 10 - June 15	24 hours per day	To the spill cap up to 100 kcfs
Bonneville	June 16 - July 20	24 hours per day	Alternating between 95 kcfs /95 kcfs vs. 85 kcfs during the day/121 kcfs at night
Bonneville	July 21 - August 31	24 hours per day	75 kcfs during the day/GC at night
Bonneville	April 10 - June 20	24 hours per day	Minimum spill is 75 kcfs
Bonneville	June 21 - August 31	24 hours per day	Minimum spill is 50 kcfs

A - No voluntary spill from April 10 to June 14 in years when forecasted seasonal average flows are less than 125 kcfs.

B - No voluntary spill from April 3 to May 31 in years when forecasted seasonal average flows are less than 65 kcfs on the Snake River.

4.1.4 Spring Creek Hatchery Spill

In 2008, the Corps, BPA, NOAA Fisheries Service and the USFWS entered into a Memorandum of Agreement regarding Spring Creek National Fish Hatchery fish production reprogramming. Under the Memorandum of Agreement, a portion of the annual production was moved to the Bonneville Hatchery, on Tanner Creek below Bonneville Dam, thereby eliminating the need to release fish in March from Spring Creek National Fish Hatchery, and the resultant requests for spill at Bonneville Dam. As a result, there were no spill operations in March 2010 for Spring Creek National Fish Hatchery fish releases. This agreement is in effect from 2009 through 2011.

4.1.5 Fish Test Operations

During 2010, there were two 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 with NOAA Fisheries providing concurrence on the final study plan for each test conducted. The special spill operations were:

1. Bonneville Passage and Survival Test
2. John Day Spillway Weir Test

Bonneville Passage and Survival Test
The Bonneville fish passage and survival test spill operation was randomly alternating spill in two day blocks of 85 kcfs during daytime hours and to 121 kcfs at night vs. a constant 95 kcfs for 24 hours per day from June 16 to July 20. Although the instructions for the fish test were issued effective June 16 as scheduled, the operation could not be implemented until July 2 because the total river flows were too high to support the fish test.

The objectives of this test were to assess passage distribution and efficiency metrics, forebay retention, tailrace egress, and survival for subyearling chinook under the two prescribed spill treatments.

This test resulted in spill discharge ranging from 84 to 121.6 kcfs, which produced TDG levels fluctuating between 113.1 to 119.1 percent as shown on the weekly graphs in Appendix E.

John Day Spillway Weir Test
A two treatment spill test began on April 10 and concluded on July 21. The spill operation was randomly alternating spill in two day blocks of 30 percent of total flow for 24 hours per day vs. 40 percent of total river flow for 24 hours per day.

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 prescribed spill treatments.

The test resulted in spill discharge ranging from 23.2 to 147.1 kcfs, which produced TDG levels fluctuating between 102.0 to 119.8 percent as shown on the weekly graphs in Appendix E.

4.1.6 Turbine Outages Effecting Spill
On a daily or weekly basis, unit outages can affect the spill volume at the dams by causing additional involuntary spill. There was one long-term (greater than one month) unit outage on the lower Snake River and twelve long-term unit outages on the lower Columbia River:

- Lower Granite One long-term unit outage: Unit 3 was forced out of service all year because of a damaged field ground and is awaiting repairs.

- McNary Four long-term unit outages: Units 2 and 7 were out from July 1 through December 28 for turbine rewinds. Units 3 and 4 were out of service from July 1 through August 28 for transformer replacement.
- The Dalles Five long-term unit outages: Four units were out of service for their annual maintenance and turbine blade seal replacement: Unit 5 from June 21 through July 28; Unit 6 from April 19 through June 10; Unit 11 from June 12 through August 13; Unit 13 from April 5 through May 20. Units 11 and 12 were out of service from March 16 through April 27 for station service upgrade.

- Bonneville Three long-term unit outages: Unit 7 was out of service through June 6 for turbine rehabilitation and generator rewind. Unit 9 was out of service through October 14 for turbine rehabilitation and generator rewind. Unit 11 was out of service all year due to cracks in the generator rotor.

4.1.7 Voluntary Spill

In 1998, the Corps RCC staff developed a BiOp spill program for daily operational monitoring of BiOp spill discharge rate and to calculate the amount of BiOp spill that should occur at the various dams. Since the spill operation at many of the dams change each year, the program that calculates BiOp spill discharge rate must be modified to calculate the corresponding voluntary spill. The amount of voluntary spill discharge rate for each dam is shown in Figures D-1 through D-8 and listed in Tables D-1 through D-8 (Appendix D). Additionally, 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.

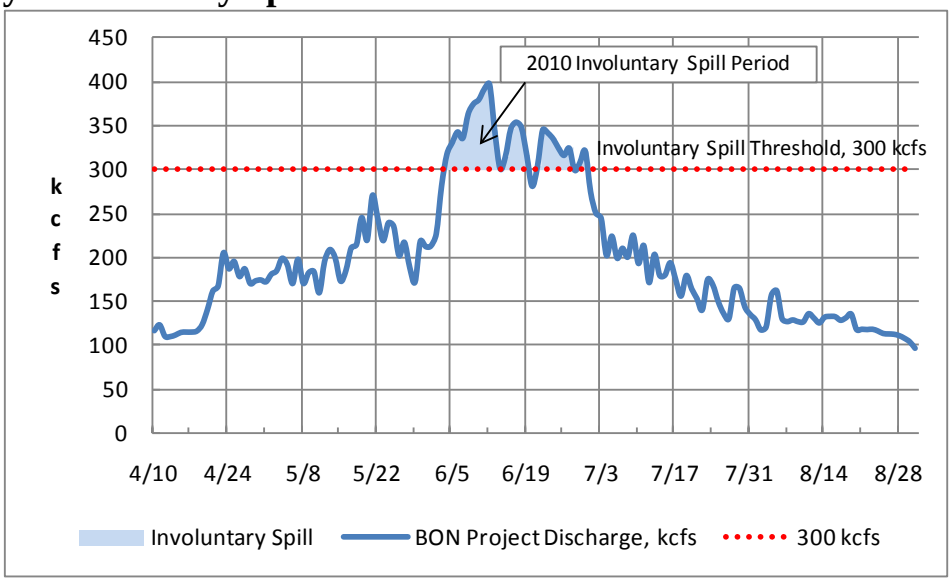
During 2010, the voluntary spill called specified in the 2010 Spring and 2010 Summer FOPs occurred from April 3 to August 31 at the lower Snake River dams, and from April 10 to August 31 at the lower Columbia River dams. Table D-9 (Appendix D) details the amount of voluntary spill volume that occurred at the individual dams during the last eleven years.

During most spill seasons, there are both voluntary and involuntary spill on the lower Columbia and Snake rivers, even during a low water year (e.g. 2001). Table D-12 (Appendix D) provides the total dam outflow volume, measured in thousands of acre-feet (kaf) for each year including the eleven-year total outflow volume average. Based on the total dam outflow volume amounts shown on Table D-12, the 2010 water year had a slightly below average total dam outflow volume. Table D-10 shows the average voluntary (labeled FOP Spill) and involuntary spill at each dam during the 2010 spill season.

4.1.8 Involuntary Spill

Involuntary spill occurred at several dams on the lower Columbia River from June 4 through July 1 when the lower Columbia River total river flow exceeded the 2010 involuntary spill threshold of 300 kcfs. In 2010, Bonneville Dam set the involuntary spill threshold for the lower Columbia River because of two main factors: (1) the constant FOP spill operation of 100 kcfs; and, (2) the number of unit outages. Since McNary, John Day and The Dalles dams spill a percent of the total river flow, their spill discharge increases as the total river discharge increases, but Bonneville's FOP spill discharge remains at 100 kcfs. As a result, Bonneville has involuntary spill before any of the other lower Columbia River dams. Especially true this year with three unit outages at Bonneville Dam (see 4.1.6 for more details). Figure 3 shows when the flows at Bonneville Dam exceeded the involuntary spill threshold.

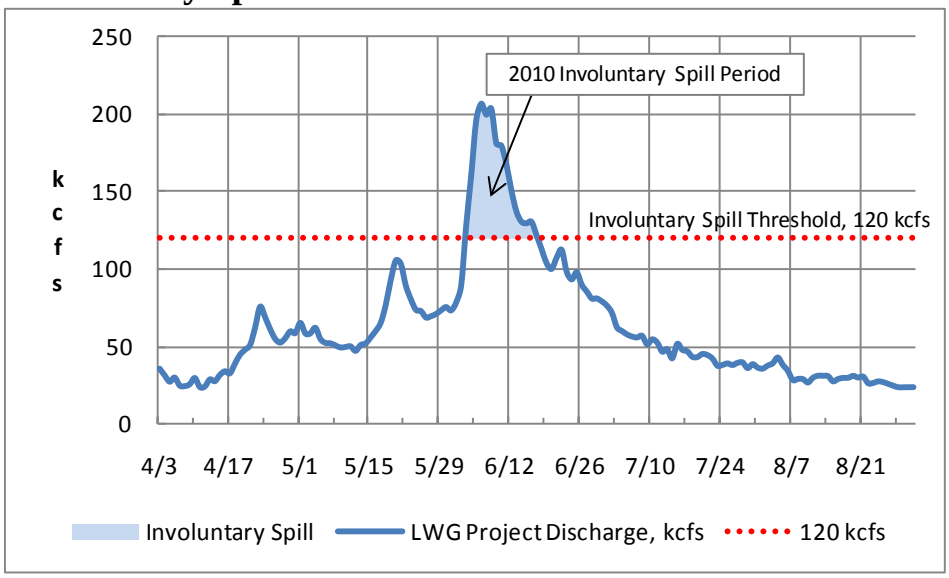
FIGURE 3
Days Involuntary Spill Threshold is Exceeded at Bonneville Dam



Bonneville Dam had the most involuntary spill of the lower Columbia River dams with 2,454 kaf from June 4 to July 1 (28 days). McNary Dam was 1,347 kaf from June 5 to June 29 (25 days). John Day involuntary spill was 19 kaf on June 14 (1 day). The Dalles involuntary spill was 6 kaf on June 5 (1 day).

Involuntary spill occurred at several dams on the lower Snake River from June 3 through June 28 when the lower Snake River total river flow exceeded the 2010 involuntary spill thresholds of 120 kcfs. In 2010, the Lower Granite Dam set the involuntary spill threshold for the lower Snake River because of two main factors: (1) the constant FOP spill operation of 20 kcfs; and, (2) the number of unit outages. Lower Granite's FOP spill operation of spilling 20 kcfs is a lower discharge than Little Goose, Lower Monumental and Ice Harbor dams, which spill either a percent of the total river flow or to a spill cap. As a result, Lower Granite has involuntary spill before any of the other lower Snake River dams. This is especially true when Lower Granite Dam had one unit out of service as it did this year (see 4.1.6 for more details). Figure 4 shows when the flows at Lower Granite Dam exceeded the involuntary spill threshold.

FIGURE 4
Days Involuntary Spill Threshold is Exceeded at Lower Granite Dam



Lower Granite Dam had the most involuntary spill of the lower Snake River dams with 1,735 kaf from June 3 to June 18 (16 days). Little Goose had the least involuntary spill of any of the lower Snake River dams with 675 kaf involuntary spill from June 5 to June 11 (7 days). Lower Monumental involuntary spill was 815 kaf from June 5 to June 16 (12 days). Ice Harbor involuntary spill was 969 kaf from June 4 to June 28 (25 days).

The FOP spill tables in Appendix D indicate amounts spilled at the lower Columbia River and Snake River dams. As Table D-10 shows, actual spill discharge rate was higher than the estimated FOP spill discharge rate because of the large amount of involuntary spill that occurred with the high runoff experienced in 2010.

The impact of high flows on TDG levels was sizeable because of the duration of the high flows and the shape of the runoff. As a result, there were 167 Type 1 condition instances (flows in excess of powerhouse capacity) system-wide with 82 Type 1 condition instances on the lower Snake River Table F-3A (Appendix F) and 85 TDG instances on the lower Columbia River Table F-3B. Of the total 234 TDG instances system-wide, 166 were due to high runoff flows and flood control efforts. More detailed information on the dam specific TDG instances is provided in Part 5 of this report.

4.2 Use and Development of the SYSTDG Model

The SYSTDG model is used to forecast the TDG levels on the Columbia and lower Snake River FCRPS dams and it is used to assist in setting daily spill caps, and evaluating various spill operations as part of planning or litigation efforts. The SYSTDG model estimates TDG pressures resulting from dam operations on the Columbia River from Grand Coulee Dam to Bonneville Dam, also on the lower Snake River from Lower Granite Dam to the confluence with the Columbia River, and from Dworshak Dam on the Clearwater River to its confluence with the Snake River. The parameters of total river flow, spill discharge,

wind, water temperature, forebay and tailwater elevations, barometric and total gas pressures, pertinent tributary data, and spill patterns are incorporated into the SYSTDG model forecasts. It also takes into consideration the specific hydraulic design of the dams, unique river hydrologic conditions, and the accumulative effects of dam management of the watershed.

The 2008 BiOp/2010 Supplemental BiOp, RPA Action 15 calls for two specific actions associated with the SYSTDG model as follows:

- Update the SYSTDG model to reflect modifications to spillways or spill operations.
- 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.

2010 Updates of the SYSTDG model

Consistent with RPA Action 15 the following actions occurred in 2010:

1. Changed the spill patterns in the model to the ones used for that year's spill operations.
2. Performed TDG monitoring studies to measure the effects the spill wall at The Dalles and John Day TSWs.
3. Changed the equations in SYSTDG to reflect the results of the 2009 TDG monitoring studies.
4. Changed the TDG calculations of instances when TDG levels exceed state WQS to match the modified state WQS.
5. Updated the Bonneville second powerhouse corner collector TDG production equation.
6. Chief Joseph TDG production equation was updated using the 2009 TDG monitoring study data.

In order to obtain information to update the SYSTDG, two monitoring studies were done to evaluate the TDG generation associated with the new physical structures recently installed. Part 4.3 provides detailed information on TDG monitoring studies performed in 2010.

Use of SYSTDG

During the 2010 spill season, the Corps' RCC Water Quality Unit used the SYSTDG model to forecast the TDG levels at the Corps' Columbia and Snake River dams to assist in setting daily spill caps and planning of spill test operations at Bonneville Dam in 2010. The SYSTDG model is typically used from April through mid May, and from mid June through July. When total river discharges are so high that involuntary spill is occurring, the SYSTDG model is used to set the initial spill caps for 125, 130 and 135 percent TDG, but is not used daily during these high flow periods. The SYSTDG model is also not used when total river discharges are so low that the FCRPS hydro-system is operating at minimum generation, since spill caps are not changed. This low flow period is typically in August but may also occur in April, depending on the runoff. To better evaluate proposed spill caps, the RCC Water Quality Unit uses both the previous year's SYSTDG statistical

evaluation and the predictive errors for each FMS. These predictive errors for the FMS gauges are shown on Tables 5 and 6 below.

The 2009-2010 SYSTDG model planning study evaluated the various summer spill options for Bonneville Dam, which included a constant spill at specified discharge rates (85, 90, 95, 100, and 120 kcfs). These various spill options were compared against the 2010 Supplemental BiOp spill operation of 85 kcfs or 75 kcfs during the day and to the gas cap at night. The SYSTDG model planning evaluations were used in the decision making process for spill management in the 2010 spill season.

Statistical Evaluation of the SYSTDG Model

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

1. Continued to use the model as an effective tool in managing spill as directed in RPA Action 15;
2. Provided the predictive error for each FMS gauge;
3. Used as part of a peer review process that will establish the model as the TDG model for the Columbia and Snake rivers; and
4. Identified 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 model statistical evaluation for 2010 as provided by the Corps' Engineering Research Development Center. 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 2010 fish passage season on the Columbia River from Grand Coulee to Bonneville and on the lower Snake River from Dworshak to Lower Granite Dam. This is the first year that the evaluation included Grand Coulee to Wells dams reach. An evaluation of the Grand Coulee to Wells dams reach was included for two reasons:

1. There was scheduled spillway discharges at Chief Joseph and Grand Coulee dams during June of 2010;
2. Because of the effectiveness of the new flow deflectors at Chief Joseph Dam, there may be a change in the frequency and magnitude of spilling during high flows to better management power generation and TDG production. This is currently being evaluated but no conclusions available yet.

The purpose of this statistical evaluation is to quantify the uncertainty of the SYSTDG model estimates and improve modeling accuracy and reliability. This evaluation was conducted by comparing SYSTDG-calculated TDG pressures to those observed TDG

pressures as measured at the FMS gauges located in the forebays and tailwaters of Corps FCRPS dams within the Columbia Basin.

The SYSTDG model simulations were run for the 2010 spill season for each dam and river reach individually so that predictive errors could be calculated independently. The predictive error is defined as the difference between the hourly observed and calculated TDG pressure or saturation, 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 dam releases. In most cases, the tailwater FMS 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 dam tailwater FMS and are shown on Tables 5 and 6. 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 through August 31 for the lower Columba and lower Snake River dams. 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 differed by more than 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 included in the SYSTDG model user's manual found at http://www.nwd-wc.usace.army.mil/tmt/wqnew/systdg_model/users_manual.pdf.

TABLE 5
Statistical Summary of the Predictive Errors At Forebay FMSs

		Predictive Error at Forebay FMS* (Saturation)									
Station		LGSA	LMNA	IHRA	MCNA	WEL	CHJ	JDY	TDA	BON	CWMW
Number of		3671	3671	3671	3672	3196	3672	3672	3653	3671	3672
Average		0.8	0.8	-0.5	0.4	-0.5	1	0.5	-0.8	0.2	-1
Standard Deviation		1.7	1.7	1.5	1.4	1.1	2.1	1.2	1.5	0.9	1.2
Maximum		5.8	5.8	5.3	5.4	2.6	6.4	5.1	3	4.2	3.7
Minimum		-3.3	-3.3	-5.7	-4.2	-6	-5.9	-3.8	-5.5	-3.9	-3.8
TDG Predictive Error for Percentile Occurrence (mm Hg)	5	-1.9	-1.9	-3.1	-1.8	-2.2	-2.7	-1.1	-3.9	-1.3	-2.6
	10	-1.4	-1.4	-2.6	-1.2	-1.7	-1.9	-0.8	-3.2	-1	-2.3
	25	-0.4	-0.4	-1.6	-0.4	-1.1	-0.4	-0.3	-1.4	-0.4	-1.8
	50	0.6	0.6	-0.4	0.4	-0.4	1	0.3	-0.5	0.2	-1.2
	75	1.9	1.9	0.5	1.2	0.1	2.7	1.2	0.2	0.8	-0.3
	90	3.1	3.1	1.3	2.2	0.7	3.6	2.1	0.8	1.4	0.6
	95	3.8	3.8	1.8	2.9	1	4.1	2.5	1.1	1.7	1.3

TABLE 6
Statistical Summary of the Predictive Errors At Tailwater FMSs

		Predictive Error at Tailwater FMS* (Saturation)											
Parameters/Stations		DWQI	LGNW	LGSW	LMNW	IDSW	GCGW	CHQW	MCPW	JHAW	TDDO	CCIW	WRNO
Number of		764	3347	2819	2698	2643	217	296	2015	1840	1938	2814	3672
Average		0.7	-1.6	-0.2	-0.2	0.1	-4.3	-0.9	0.1	-0.5	-0.6	-0.5	-1
Standard Deviation		0.6	2.3	1.1	1.5	1.1	4.1	1.5	1.8	1.7	0.9	1	1.2
Maximum		4.3	8.2	5.4	7.3	6.6	3.4	6.8	6.4	3.2	2	2.4	3.6
Minimum		-0.7	-8.7	-4.5	-6.2	-4.9	-20.4	-5	-5.6	-4.4	-5	-6.8	-6.3
TDG Predictive Error for Percentile Occurrence (mm Hg)	5	0	-6.5	-1.9	-2.7	-1.5	-11.9	-2.8	-2.7	-3.2	-2.2	-1.7	-2.8
	10	0	-4.6	-1.6	-2.1	-1.2	-10	-2.3	-2.1	-2.7	-1.8	-1.1	-2.5
	25	0.3	-2.5	-0.9	-1.3	-0.7	-6.4	-1.7	-1.3	-2	-1.2	-0.7	-1.8
	50	0.6	-1.3	-0.3	-0.1	0	-3	-1.1	0.1	-0.6	-0.5	-0.4	-1.1
	75	1	-0.3	0.4	0.9	0.7	-1.9	-0.5	1.6	0.8	0	0	-0.2
	90	1.5	0.5	1	1.5	1.6	-0.5	1	2.2	1.9	0.5	0.3	0.6
	95	1.9	1.3	1.4	1.8	2.1	0.5	1.7	2.6	2.1	0.8	0.5	1.1

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 2010 (Tables G7 and G8) were slightly larger than predictive errors estimated at tailwater stations (Tables G9 and G10). A review of model performance indicates that 6 out of the 10 forebay stations had standard errors greater than 10 mm Hg compared to only 4 out of 10 tailwater stations. The average predictive errors at all the forebay stations were less than 1 percent of saturation. The correlation between strong winds and declining TDG pressure at forebay stations were again evident during the 2010 spill season.

- The TDG exchange, transport, and mixing of Bonneville Dam releases during the 2010 spill season resulted in a significant improvement in the prediction of TDG pressures at the Camas/Washougal station when compared to the formulation used in 2009. The new formulation for TDG exchange associated with the Bonneville second powerhouse corner collector was the primary reason for the improvement in model estimates.

- The prediction 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 prediction error at the Dalles tailwater station was estimated to be 6.4 mm Hg while the corresponding standard error in the forebay of Bonneville Dam was only 7.2 mm Hg. The impact of the spillway training wall on the estimation of TDG pressures at the downstream monitoring stations was small

- A spillway flow deflector was added to John Day spill bay 20 for the 2010 spill season. The spill patterns at John Day Dam were changed during the 2010 spill season to include the new locations for the spillway weirs and added spillway flow deflectors. Both summer and spring spill patterns were modified to incorporate these structural changes. The estimated TDG exchange was consistently over-estimated during spill discharges greater than 120 kcfs and under-estimated conditions for low flows less than 60 kcfs. The influence of the different spill patterns needs to be more completely integrated into the John Day TDG exchange model to improve the forecasting accuracy.

- The SYSTDG simulation of tailwater TDG pressures at McNary Dam were less reliable (standard error of 13.8 mm Hg, average error of 0.7 mm Hg) than conditions simulated during 2009. A closer integration of different spill patterns is a likely source for improving the TDG production model at McNary Dam.

- The TDG production from Chief Joseph Dam and fate throughout the Wells Dam pool were evaluated in SYSTDG for the first time in 2010. The spill discharges ranged from 10 to 105 kcfs during the month of June. The observed TDG saturations approached 120 percent of TDG saturation for spill discharges of 100 kcfs. The TDG response at the tailwater monitoring station was found to vary with tailwater stage for selected spill levels. The accuracy of estimates of TDG pressure in Chief Joseph releases were comparable to other dams evaluated in this review.

- The TDG production from Grand Coulee Dam and transport throughout the Chief Joseph pool were evaluated with the SYSTDG model for operations observed in 2010. The average predictive error for Grand Coulee Dam tailwater FMS (GCGW) was nearly 3 times larger than the next highest average error estimate at Lower Granite Dam (LGNW) and therefore warrants further evaluation. The potential sources of high predictive error associated with GCGW FMS could be the result of one or all of the three following factors:

    1. GCGW FMS SYSTDG TDG production equations are underdeveloped;
    2. GCGW FMS may not be located in well mixed waters; and
    3. GCGW FMS could be malfunctioning and the data is erroneous

  In order to address the large predictive error associated with GCGW FMS, it is necessary that the TDG exchange equations be updated based on data collected above and below Grand Coulee Dam under a range of operation conditions including both regulating outlet and drum gate releases. A field study of the TDG exchange during spill operations at Grand Coulee Dam would also provide for an assessment of the monitoring stations at Grand Coulee Dam.

- The TDG exchange formulation for Ice Harbor Dam proved to be one of the most reliable estimates of tailwater TDG pressure on the Snake River. The consistent performance of this TDG exchange model is related to the importance of tailwater depth of flow on TDG generation.

- 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 2010. The standard prediction error for the tailwater station below Lower Monumental Dam was the third highest behind John Day and Grand Coulee dams. The TDG exchange characteristics at Lower Monumental Dam involve a complex spill pattern and the substantial entrainment of powerhouse flows into aerated spillway flows. A TDG production formulation developed from conditions observed in 2009 was applied to the proposed spill patterns presented in the fish passage plan.

- The application of the existing TDG exchange formulation for Little Goose Dam preformed well based on the revised spill patterns. A noted short coming of model predictions during the 2010 season involved the under-estimation of TDG pressures during peak spillway discharges.

- The SYSTDG model provided reliable estimates of TDG exchange at Lower Granite Dam during the 2010 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.

- A challenge in providing estimates of TDG exchange in releases from Dworshak include providing estimates of both the TDG content in powerhouse, spillway, and regulating outlet flows. The SYSTDG model produced accurate estimates of the TDG pressure at the tailwater fixed monitoring station with a standard error of estimate of only 4.4 mm Hg. The larger prediction errors were generally associated with periods of TDG generation in powerhouse releases.

4.2.3 Future Improvements and Developments

The FCRPS BiOp RPA Action 15 calls for: "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." The SYSTDG model is used to predict river TDG levels, and it is the Corps' perspective that modifying the SYSTDG model to perform wind forecasting is inappropriate.

The following improvements and maintenance activities to the SYSTDG model are recommended for 2011.

- The results from the field studies investigating of TDG exchange at The Dalles and John Day dams should be incorporated into the TDG models at these dams. The findings regarding the adequacy of the fixed monitoring stations for TDG management should also be summarized.

- The TDG exchange description for Lower Granite Dam should be updated to more accurately estimate conditions developing for lower spillway flows and summertime spill patterns.

- The complete spill pattern tables for the summer, spring, and special operations should be entered into each of the dam pages.

- The TDG exchange formulation for Lower Monumental Dam should be updated to improve the accuracy at high spillway discharges and include data from multiple years. The identification of the influence of forebay TDG pressures on data observed at the tailwater FMS should be quantified.

The description of TDG exchange during turbine operations at Dworshak Dam should be developed and included in the SYSTDG model. The production relationship for regulating and spillway operations at Dworshak Dam should be developed and incorporated into the TDG exchange model.

4.3 TDG Monitoring Studies

TDG monitoring studies are included as actions associated with the TDG TMDL and to update the SYSTDG model.

During the 2010 spill season TDG monitoring studies were conducted at The Dalles and John Day dams. The TDG monitoring study conducted at The Dalles Dam occurred from June 3 through September 3, 2010. The purpose of the study was to evaluate the impacts of the new bay 8-9 spillwall on TDG exchange and re-evaluate the effectiveness of the existing tailrace FMS below the dam. An array of temporary fixed monitoring stations was located across from the tailwater with two stations below the powerhouse. Data from these stations will be used to better understand the TDG contributions from the powerhouse verses from the spillway. Manual sampling also occurred on transects to test water velocities and dissolve oxygen gradients. The information is expected to be available before the 2011 spill season and will be used to update SYSTDG model.

The TDG monitoring study conducted at John Day Dam occurred after the construction of the bay 20 spillway flow deflector. The purpose of the study was to evaluate the interaction of powerhouse and spillway flows, the TDG generation impact of the John Day spillway weir, and whether the tailwater FSM was representative of conditions. The study included three transects to measure the distribution of dissolved oxygen and flow in the

immediate tailrace area using seven discrete sample events spanning from May through August. The information is expected to be available before the 2011 spill season and will be used to update SYSTDG model.

Part 5 Instances of TDG Exceeding WQS

During 2010, most of the TDG instances that document when the WQS have been exceeded occur when the involuntary spill thresholds have been exceeded. As shown in Figures 3 and 4, the TDG instances occur when total river flows exceed 300 kcfs on the lower Columbia and 120 kcfs on the lower Snake River. Part 5 discusses the TDG instances.

5.1. TDG Instance Calculation Methods

Calculations and reporting in Part 5 are consistent with the calculation methods adopted in 2010 and described in Part 1.1.7 of this report.

5.2 TDG Instances - Oregon/Washington Calculations

5.2.1 115 percent and 120 percent TDG Instances

Unless otherwise specified, all TDG instances discussed in this report use the Oregon/Washington calculation method.

Table 7 provides a summary of TDG instances for 1999 through 2010 spill seasons. As indicated in Table 7, the Camas/Washougal, Ice Harbor forebay, and Bonneville tailwater FMS had the highest number of TDG instances during 2010 and were the most difficult to maintain below the 115 percent forebay or 120 percent tailwater TDG standards.

TABLE 7
1999 - 2010 Spill Seasons
Number of TDG Instances Exceeding WQS

Water Quality Gages	2010 Qty.	2009 Qty.	2008 Qty.	2007 Qty.	2006 Qty.	2005 Qty.	2004 Qty.	2003 Qty.	2002 Qty.	2001 Qty.	2000 Qty.	1999 Qty.	Average
Lower Granite Forebay	0	0	0	0	0	0	0	0	0	5	2	0	1
Lower Granite Tailwater	15	15	35	0	28	0	0	15	17	0	4	15	12
Little Goose Forebay	14	19	34	0	24	0	3	10	17	0	2	39	14
Little Goose Tailwater	7	0	23	0	19	0	0	6	6	0	9	6	6
Lower Monumental FB	14	26	54	11	56	6	1	19	49	0	28	44	26
Lower Monumental TW	14	21	32	7	29	7	1	10	6	0	12	26	14
Ice Harbor Forebay	31	44	55	31	51	3	4	35	24	0	34	44	30
Ice Harbor Tailwater	11	25	31	0	22	3	2	4	6	0	4	12	10
McNary Forebay - WA	11	4	21	6	31	8	10	24	43	1	14	22	16
McNary Forebay - OR	--	--	--	--	--	11	23	32	45	5	22	19	22
McNary Tailwater	23	5	28	1	32	1	7	12	31	0	17	50	17
John Day Forebay	1	9	14	0	20	2	0	10	11	0	1	8	6
John Day Tailwater	0	7	17	3	38	3	0	0	29	0	12	43	13
The Dalles Forebay	0	11	17	8	40	6	5	11	18	0	5	1	10
The Dalles Tailwater	0	0	2	0	10	0	0	4	11	0	5	5	3
Bonneville Forebay	14	32	27	3	51	3	1	17	30	0	14	19	18
Cascade Island	27	24	57	0	61	0	---	---	---	---	---	---	28
Warrendale	--	--	--	--	--	---	0	1	19	0	6	2	5
Camas/Washougal	52	66	68	29	63	16	14	33	65	2	58	51	43
Total Number of Exceedances	**234**	**308**	**515**	**99**	**575**	**69**	**71**	**243**	**427**	**13**	**249**	**406**	**267**

5.2.2 Instances of TDG Exceeding 125 percent WQS

During the 2010 spill season, there were 555 instances of hourly TDG exceeding either the Oregon or Washington state standards of 125 percent TDG (a one hour standard in Washington, and a two hour standard in Oregon). Table F-6 (Appendix F) provides information on the range and number of hours over 125 percent of TDG. In 2010 there were a high number of instances above the hourly 125 percent TDG when compared to the last ten years when the hourly instance tracking began as shown in Table F-5. Involuntary spill due to high runoff was a primary factor resulting in 552 hours of instances above 125 percent TDG relative to the Oregon standard. 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.

Additional discussion and breakdown of those 555 instances is as follows. Five of the eight lower Columbia River and lower Snake River dam FMSs exceeded the hourly value of 125 percent TDG. Lower Granite Dam contributed 175 hours; Little Goose Dam contributed 101 hours; Lower Monumental Dam contributed 166 hours; Ice Harbor Dam contributed 112 hours and McNary Dam contributed 1 hour. The highest hourly reading was at Little Goose tailwater with 142.6 percent as shown on Table F-6 and Table F-4. Graphs of the lower Snake and Columbia River dams' 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 dam specific TDG instance of the 125 percent TDG standard is provided in Part 5 of this Report. A table of the high 12 hour TDG averages is provided at the end of each monthly Court report found in Appendix E.

In 2010, there were two special spill operations to pass debris that contributed to the instances above 125 percent TDG, one each at Lower Granite Dam and Little Goose Dam.

On June 7, the Lower Granite spilled to prevent excessive debris build-up that threatened to impede the RSW operations, plug intake structures, and potentially harm fish. During the Lower Granite debris spill, TDG levels rose for two hours and TDG levels ranged from 132.5 to 133.8 percent. On June 10, the Little Goose spilled to prevent building up of excessive debris for the same reasons. During the Little Goose debris spill, TDG rose to 142.6 percent for one hour. There was a debris spill at McNary on July 12, but TDG rose only to 122.1 percent during that operation so it did not exceed the 125 percent TDG standard.

5.2.3 Comparison of Annual Daily Instances

Table 8 shows the number of daily instances of TDG instance above WQS in 2010 was slightly lower than the twelve year average. This nearly average 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 below average at 78.9 percent of normal (1971 - 2000), and the June runoff was slightly above average, the duration of high flows resulted in a high number of daily instances during that period.

TABLE 8
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 (%)	Normal Runoff at TDA[1]
2010	2504	234	9.3	90.7	78.9
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
1999	2754	406	14.7	85.3	142.7
Average	**2640**	**267**	**10.2**	**89.8**	**100.6**

[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, ODEQ and TMT requested the Corps track the causes of instance where TDG exceeded WQS. Table F-1 (Appendix F) provides a listing of the three causes or instance types. The Corps tracked the daily TDG instance types for the forebay and tailwater of

each of the Corps FCRPS dams during the 2010 spill season. Each type of instance represents conditions that cause daily TDG levels to exceed WQS. The 2010 tracking results compared with prior years are summarized in Table 9. Daily and by-dam detail can be found in Appendix F. The daily instance type designation given to each TDG instance is based on the Corps determination of causation.

During the 2010 spill season, there were a total 234 instances out of 2,504 gauge-days ([number of TDG gauges] x [days in spill season]) in which the TDG levels were above the TDG criteria. There were 167 instances of a Type 1 condition, which the Corps could not prevent. The other 67 TDG instances were Type 2 and 3 instances as discussed in Table 9. The 234 instances in which the TDG levels were above the TDG criteria was slightly lower than the 267 twelve-year average TDG instances for a spill season.

It is worth noting that certain types of TDG instances, such as Types 1 and 2a, associated with high flows and malfunctioning gauges, respectively, occur every year and are a normal part of reservoir operations. Even so, efforts continue to be made to reduce daily instances when possible.

TABLE 9
2003-2010 Spill Seasons
Types and Numbers of TDG Instances

8 Year Average	2010	2009	2008	2007	2006	2005	2004	2003	TYPE #	DEFINITION
174	166	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.
6	1	1	1	1	45	0	0	0	**1a**	Planned and unplanned outages of hydro power equipment including generation unit, intertie line, or powerhouse outages.
6	0	1	11	0	14	1	6	17	**2**	TDG exceedances due to the operation or mechanical failure of non-generating equipment.
6	7	17	10	0	1	1	6	7	**2a**	Malfunctioning FMS gauge, resulting in fewer TDG or temperature measurements for setting TDG spill caps.
82	60	98	81	93	75	39	48	159	**3**	TDG exceedances due to uncertainties when using best professional judgment, SYSTDG model and forecasts.
274	**234**	**308**	**525**	**100**	**621**	**70**	**67**	**269**		**Totals**

5.2.5 Recurring High TDG Instances

There are three TDG gauges that are difficult to manage and avoid TDG instances from voluntary and/or involuntary spill: Camas/Washougal, Ice Harbor forebay, and Bonneville Tailwater at Cascade Island. The McNary tailwater gauge had the fourth highest number of TDG instances in 2010 spill season, which is not typical. A review of the 1999-2010 daily TDG instances indicates the Camas/Washougal, Ice Harbor forebay, and Cascade Island have a history of recurring daily TDG instances as a result of high flows and unit outages. The following is a discussion about each of these high TDG instance gauges.

5.2.5.1 Camas/Washougal

The Corps continues to use the Camas/Washougal gauge as part of the Court ordered operations even though the states of Oregon and Washington have removed this gauge as a compliance point. The Camas/Washougal gauge has the highest number of daily TDG instances with an average of 43 TDG instances per year over the last twelve years. This trend continued into the 2010 spill season. As indicated in Table F-3B (Appendix F), Camas/Washougal had a total of 52 TDG instance in 2010: with 19 Type 1 instances and 33 Type 3 TDG instances. 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 highly influenced by natural conditions such as winds, barometric pressures, changes in daily solar radiation, and swings in water temperatures than other TDG gauges. Production of oxygen by aquatic plants is also believed to be involved in causing some diurnal variations in TDG at this location.

The daily TDG instances at this gauge are usually classified as Type 3 instances: TDG instances due to uncertainties when using best professional judgment, SYSTDG model and forecasts. But there are some years when the precipitation and runoff are high resulting in the TDG instances at the Camas gauge being classified primarily as Type 1 condition associated with high runoff and flood control operations.

5.2.5.2 Ice Harbor Forebay

The Ice Harbor forebay gauge has the second highest number of daily TDG instances with an average of 30 TDG instance per year over the last twelve years. This trend continued into the 2010 spill season. As indicated in Table F-3A, the Ice Harbor forebay gauge had a total of 31 TDG instances in 2010 spill season: 15 Type 1 instances, and 16 Type 3 instances. The frequency of TDG instances of the 115 percent daily standard at the Ice Harbor forebay gauge is similar to the Lower Monumental forebay gauge. This suggests that the degassing characteristics in the reach between Lower Monumental Dam and Ice Harbor Dam make it very difficult to manage to the Ice Harbor forebay TDG criterion of 115 percent. The cumulative impacts of spill operations on the lower Snake River also contribute to the higher TDG in the river as the water moves downstream.

5.2.5.3 Cascade Island

The Bonneville tailwater gauge at Cascade Island has the third highest number of daily TDG instances with an average of 28 TDG instance per year over the last six years. Cascade Island was installed in 2004 and became the official Bonneville tailwater gauge in 2005, replacing the Warrendale gauge. This trend of high TDG instances continued into the 2010 spill season. As indicated on Table F-3B of Appendix F, Cascade Island had a total of 27 TDG instances in 2010 spill season: 26 Type 1 instances, and 1 Type 2a instances.

5.2.5.4 McNary Tailwater

The McNary tailwater gauge has the seventh highest number of daily TDG instances with an average of 17 TDG instance per year over the last twelve years (1999 - 2010) as indicated in Table 7. The 2010 spill season was an exception to this trend and it had the

fourth most TDG instances. As indicated on Table F-3B of Appendix F, the McNary tailwater gauge had a total of 23 TDG instances in the 2010 spill season: 21 Type 1 instances, and 2 Type 2a instances. This shift was attributed to the runoff pattern observed in 2010 and the relatively low powerhouse discharge capability.

5.3 TDG Instances - Washington Calculations

Part 5.3 provides the detail tracking of the Washington method of calculating TDG instances.

5.3.1 115 percent and 120 percent TDG Instances

The revised Washington WQS require the new method of calculating the average of the 12 highest consecutive hours beginning in 2008. The Corps calculated the number of TDG instances for the 2010 spill season using this method for comparison purposes and summarized in Table 10.

TABLE 10
2010 Spill Seasons TDG Instances
Comparison of WA and OR/WA Methods

Water Quality Gages	WA - 2010 Qty.	OR/WA - 2010 Qty.	Difference Qty.
Lower Granite Forebay	0	0	0
Lower Granite Tailwater	15	15	0
Little Goose Forebay	17	14	3
Little Goose Tailwater	**8**	7	1
Lower Monumental Forebay	15	14	1
Lower Monumental Tailwater	15	14	1
Ice Harbor Forebay	37	31	6
Ice Harbor Tailwater	**11**	11	0
McNary Forebay - WA	**14**	11	3
McNary Forebay - OR	--	--	--
McNary Tailwater	26	23	3
John Day Forebay	**2**	1	1
John Day Tailwater	0	0	0
The Dalles Forebay	0	0	0
The Dalles Tailwater	0	0	0
Bonneville Forebay	19	14	5
Cascade Island	29	27	2
Warrendale	--	--	--
Camas/Washougal	67	52	15
Total Number of Instances	**275**	**234**	**41**
Tailwater Instances	**104**	**97**	**7**
Forebay Instances	**171**	**137**	**34**

5.3.2 Comparison of Calculation Methods

As Table 10 indicates, there were 41 more TDG instances using the Washington method compared to the Oregon/Washington method. This suggests the Washington method is more stringent of the two methods. This is a consistent characteristic observed since 2008 when the Washington method was first tracked. These 41 additional TDG instances occurred primarily at dam forebay gauges, with the Camas/Washougal gauge having an additional 15 instances; the largest number of additional TDG instances for any gauge. Table 11 shows the additional TDG instances at the other forebay gauges ranged from 0 to 6.

Table 10 shows the tailwater gauges were also impacted, but to a much lesser degree. The difference between the Washington and Oregon/Washington method of calculating TDG instances resulted in the tailwater gauges increasing from 0 to 3 additional TDG instances. The two tailwater gauges with the largest gain of 2 and 3 TDG instance compared to the Oregon method were the Cascade Island and McNary tailwater gauges, respectively.

TABLE 11
Forebay Gauges Most Affected
By Changing Calculation Methods

Water Quality Gages Forebay	WA Method 2010 Qty.	OR/WA 2010 Qty.	Difference Qty.
Camas/Washougal	67	52	15
Ice Harbor Forebay	37	31	6
Bonneville Forebay	19	14	5
McNary Forebay	14	11	3
Little Goose Forebay	17	14	3
Lower Monumental Forebay	15	14	1
John Day Forebay	2	1	1
The Dalles Forebay	0	0	0
Lower Granite Forebay	0	0	0
Total Number of Instances	**171**	**137**	**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' dams. Appendix I contains a summary of the Dworshak flow augmentation and temperature moderation operations with graphs of Dworshak tailwater and Lower Granite Dam tailwater temperatures. Appendix E contains water temperature graphs that were provided in the monthly 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 the condition ended, and other general information. Table 12 provides a six year comparison of the number of days that a gauge recorded temperatures above 68°F on a daily average from 2005 through 2010. Table 12 shows that the 2010 water year was noticeably cooler than average.

TABLE 12
Number of Days Gauges Recorded Temperatures Above 68ºF on a 24 Hour Average

Location	Number of Days					
	2010	2009	2008	2007	2006	2005
LBQM	0	0	0	0	0	0
ALFI	40	54	42	29	70	50
ALQI	40	54	38	64	70	---
CHJ	0	0	0	0	0	0
CHQW	0	0	0	0	0	0
ANQW	45	76	49	78	76	65
DWQI	0	0	0	0	0	0
PEKI	0	0	0	0	0	0
LEWI	0	0	0	0	0	0
LWG	0	3	0	1	5	53
LGNW	0	0	0	1	8	0
LGSA	12	25	7	35	51	20
LGSW	11	18	6	34	48	20
LMNA	31	36	13	58	59	40
LMNW	33	31	14	59	59	44
IHRA	41	61	32	66	68	56
IDSW	39	62	36	68	69	60
PAQW	20	38	12	28	38	27
MCNA	35	60	27	63	59	49
MCPW	37	65	29	65	61	50
JDY	43	60	39	72	68	55
JHAW	42	70	41	72	68	55
TDA	40	63	34	69	67	56
TDDO	41	70	38	69	67	56
BON	37	62	27	65	64	56
CCIW	38	65	27	65	65	55
CWMW	38	65	34	66	65	58
Total	**663**	**1,038**	**545**	**1,127**	**1,205**	**925**

6.1 State Water Quality Standards for Temperature

The water temperature standards for the lower Columbia and Snake rivers as defined by the states of Idaho, Oregon, Washington and Colville Confederated Tribes are shown in Tables 13, 14 and 15.

TABLE 13
State Water Quality Standards
The Lower Snake Dams

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 1-day maximum of 20°C (68°F) due to human activities. When natural conditions exceed 1-day maximum of 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 173-201A-602	Water temperatures 22°C or less with a maximum daily average of no greater than 19°C. IDAPA 58.01.02-250-02 (b)

TABLE 14
State Water Quality Standards
The Lower Columbia River Dams

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 a 1-day maimum of 20°C (68°F) due to human activities. When natural conditions exceed a 1 day maximum of 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 173-201A-602	Unless superseded by the natural conditions, the temperature criteria for State waters supporting salmonid and steelhead spawning use is as follows: The seven-day-average maximum temperature of a stream identified as having The seven-day-average maximum temperature of a stream identified as having a migration corridor use The seven-day-average maximum temperature of a stream identified as having a migration corridor useThe seven-day-average maximum temperature of a stream identified as having a migration corridor use may not exceed 20.0 degrees Celsius (68.0 degrees Fahrenheit). OAR 340-041-0028

TABLE 15
State Water Quality Standards
The Colville Confederated Tribes

Project	Washington Standard	Colville Confederated Tribe Standard
From Northern Reservation Boundary to Chief Joseph Dam, Columbia River, RM 545.1	"Temperature shall not exceed 18° C (64.4 F) due to human activities. When natural conditions exceed 18° C (64.4 F) no temperature increases will be allowed which will raise the receiving water temperature by greater than 0.3° C (0.5 F). Incremental temperature increases resulting from point source activities shall not, at any time, exceed t=28/T+7). Incremental increase resulting from nonpoint source activities shall not exceed 2.8° C (5.4 F)." WAC 173-210A-130(21) and WAC 173-201A-030(2)	Temperature shall not exceed 18.0 C (freshwater) and 16.0 C (saline water) due to human activities. Temperature increases shall not, at any time, exceed t=28/(T+7) (freshwater) or t=12/(T-2) (saline water). Colville Tribe Standard 4-8-6(b)(3)(F):

6.2 Dworshak Operations

The 2008 BiOp/2010 Supplemental BiOp, RPA Actions 4 and 15 call for with the following Dworshak Dam specific actions. Each specific action has the associated dam operation provided:

RPA Action 4 - Storage Dam Operations:

1. Specific Action: 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).

Dam Operation: The Dworshak Dam was operated to standard flood control criteria. Dry water year conditions did not allow a shift of system flood control to Grand Coulee in the 2010 water year. At Dworshak Dam the April through July runoff totaled 1.9 Maf, which is 72 percent of average based on the period of 1971-2000.

2. Specific Action: 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.

Dam Operation: Dworshak was operated at minimum discharge throughout the fall, winter and spring until mid May. Inflows were insufficient to fill to the upper flood control rule curve by April 10, as shown on Figure I-1 in Appendix I. Refill of Dworshak Reservoir began in January and continued through June.

3. Specific Action: Provide minimum flows while not exceeding Idaho State TDG water quality standard of 110 percent.

Dam Operation: The Dworshak Dam was managed to minimum discharge from September 17, 2009 until June 8, 2010. Minimum discharge rates range from 1.1 to 1.5 kcfs. The peak discharge rate was 13.7 kcfs on June 21 during the freshet. Figure I-2 in Appendix I provides Reservoir elevation and discharge relationship.

4. Specific Action: Refill the reservoir by about June 30 to 1600 feet.

Dam Operation: The Dworshak Reservoir was refilled to elevation 1600 feet on June 24.

5. Specific Action: 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.

Dam Operation: The Dworshak Reservoir was drafted to elevation 1535 feet on August 31, and drafted to elevation 1520 feet on September 23, consistent with the agreement with the Nez Perce Tribe and as shown on Figure I-1 in Appendix I.

6. Specific Action: Regulate outflow temperatures to attempt to maintain water temperatures at Lower Granite Dam tailwater at or below the water quality standard of 68° F.

Dam Operation: Dworshak Reservoir outflows were managed to maintain water temperatures at Lower Granite Dam tailwater below 68°F as shown on Figure I-4 and Figure I-5 in Appendix I. Seasonal average discharge temperatures during flow augmentation season from 2000-2008 are shown on Figure I-4 in Appendix I.

7. Specific Action: Maximum dam discharge for salmon flow augmentation to be within state of Idaho TDG water quality standards of 110 percent.

Dam Operation: Dworshak Dam outflows were managed to provide salmon flow augmentation with two efforts as shown in Figure I-2 in Appendix I. The spring flow augmentation resulted in a peak discharge rate of 2.4 kcfs, and a total volume of 0.09 Maf released from March 31 through May 6. The summer flow augmentation resulted in a peak discharge rate of 13.6 kcfs and a total volume of 1.43 Maf from July 7 through September 23.

RPA Action 15 - Water Quality Plan:

8. Specific Action: Continued development of the CE-QUAL-W2 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 gauge) through the lower Snake River (all four Corps lower Snake River dams) to assist in real-time decision making for Dworshak Dam operations.

Progress: The CE-QUAL-W2 model was utilized extensively during the summer temperature flow augmentation for the lower Snake River as shown on Table I-1 of Appendix I. Use of the CE-QUAL-W2 model enabled the Corps, in conjunction with TMT members, to determine the best discharge sequences and durations from Dworshak Dam to meet the temperature targets in the lower Snake River. See Figure I-6 in Appendix I.

During 2010 Walla Walla District (NWW) worked with a contractor and the model developer to make significant improvements to the model. Most of the improvements were made in the pre- and post-processing of the data required to run the model and to display output. NWW is continuing to work with the contractor to further enhance the CE-QUAL-W2 model by expanding the model calibration as well as upgrading to a new version of the model.

6.3 Water Temperature Modeling

The 2008 BiOp/2010 Supplemental BiOp, RPA Action 15 also calls for the following expanded water temperature model development for the Columbia River:

RPA Action 15 - Water Quality Plan:

1. Specific Action: Expand water temperature modeling capabilities to include the Columbia River from Grand Coulee to Bonneville dams to better assess the effect of operations or flow depletions on summer temperatures.

Progress: In 2010, the Corps initiated development of a scope of work, schedule and cost estimate for this effort. The Corps expects to continue evaluating this dam and to seek funding in 2011.

Part 7 Fish Passage Summary

7.1 Biological Monitoring

The Fish Passage Center provides a summary of the gas bubble trauma monitoring results that they collected in 2010, which is included as Appendix M. The following is a summary of those results.

The monitoring of juvenile salmonids in 2010 for gas bubble trauma 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 Granite Dam, Little Goose Dam, and Lower Monumental Dam.

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 as shown in Table M-1 (Appendix M).

In all, 13,624 juvenile salmonids were examined for GBT between April and August of 2010 as shown in Table M-2. Fin signs were found in 49, or 0.36 percent, of the fish sampled at all sites as shown in Table M-3. All fish examined and determined to have signs of GBT exhibited the less severe fin signs of rank 1, where less than 5 percent of a fin area was covered with bubbles. Table M-4 compares the 2010 estimates of the overall percentage of fish with signs of GBT to past years' estimates.

The action criteria for GBT is established as 15 percent of fish showing any signs of GBT, or 5 percent of the fish sampled showing signs greater than rank 1. In 2010 the action

criteria for GBT were met at Little Goose Dam as shown in Figure M-3. Fish were sampled with signs of GBT during May, but both the prevalence and severity of GBT signs increased during early June, and increased to a maximum of 15 percent in the June 14 sample. During this time period stream flows had increased rapidly in the Snake River and the hydraulic capacity at Lower Granite Dam was very limited due to Unit 3 being out of service. Consequently, total dissolved gas levels in the Lower Granite tailrace began to exceed the TDG criteria of 120 percent on June 3, increased to a high near 132 percent on June 6, and continued to be above the 120 percent criteria in the tailrace until June 17.

A few more fish were observed at Rock Island Dam as shown in Figure M-6. The site where the most fish were observed with signs of GBT in the Federal Columbia River Power System was at Little Goose Dam as shown in Figure M-3. The percentage of fish showing signs of GBT peaked in mid June, with the percentage reached the action criteria of 15 percent.

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 exceeded in the Snake River in 2010, with the highest daily observation in 2010 being 15 percent. This was observed at Little Goose Dam on June 14.