Appendix 4

2012

Total Dissolved Gas

Management Plan

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1.0 Introduction

In various parts of the Columbia and Snake River systems, elevated levels of total dissolved gas (TDG) saturation are observed where spill occurs at dams. A *TDG Management Plan* is developed annually and is included as Appendix 4 in the annual Water Management Plan. This TDG Management Plan provides detailed information addressing TDG management measures, the process for setting spill caps, TDG management policies, and the TDG monitoring program and modeling. This plan is consistent with the 2000 U.S. Fish and Wildlife Service (USFWS) Biological Opinion, and the NMFS 2008 Biological Opinion and NMFS 2010 Supplemental Biological Opinion (NMFS 2010 Supplemental BiOp).

1.1 Background

In the late 1990s, it was recognized that development of a system-wide TDG model would assist with in-season management of voluntary spill. This idea was incorporated into the NMFS 2000 Biological Opinion, RPA Action 133, which encouraged the development of a TDG model for spill management. As a result, the Corps began developing a TDG model called "SYSTDG", which is an hourly time step model used to forecast the TDG levels at the Columbia and Snake River dams and to assist in setting daily spill caps. The SYSTDG model estimates TDG production resulting from dam operations on the Columbia River from Grand Coulee Dam to below Bonneville Dam, 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 SYSTDG model incorporates a number of variables, including the hydraulic design of the dams, the hydrologic conditions of the river unique to that particular reach, total river flow, current and forecasted conditions and the cumulative effects of project management of the river system.

The SYSTDG model was first used during the 2004 spill season as a river operations management tool to evaluate TDG on the Columbia and Snake rivers and to assist in the setting of spill caps at each of the dams where voluntary spill for fish occurred. At the conclusion of the spill season, a review of the performance of the SYSTDG model was completed and included in the *2004 Dissolved Gas and Water Temperature Monitoring Report*. The same statistical evaluation of SYSTDG model performance was done for the 2005 through 2011 spill seasons. These statistical evaluations are included in the annual *Dissolved Gas and Temperature Annual Report* for each of those spill seasons, and are also available on the RCC Water Quality Programs webpage at: http://www.nwd-wc.usace.army.mil/tmt/wqnew/

The SYSTDG model will continue to be used as a TDG management tool into the foreseeable future. Updates of the SYSTDG model occur as necessary when there are operational or structural modifications to the spillway, new spill patterns, or new TDG research that can be used to refine the model performance.

1.2 State Water Quality Standards

The federal Clean Water Act establishes the 110 percent TDG criteria for rivers which the states of Washington and Oregon adopted into their state water quality standards. The states of Washington and Oregon have authorized exceptions (rule adjustment or waiver, respectively) to

these standards as long as the elevated TDG levels provide for improved fish passage through the spillway without causing more harm to fish populations than through other passage routes.

The five year 2010-2014 Oregon TDG waiver specifies that TDG levels are not to exceed 120 percent in the tailwaters as measured as the average of the twelve highest hourly readings in any one day. Oregon no longer includes criteria for TDG in the forebays. The five year 2010-2014 Washington rule adjustment specifies that TDG levels are not to exceed 120 percent in the tailwaters and 115 percent in the forebays of downstream dams as the average of the twelve highest consecutive hourly readings in any one day. They also specify that TDG levels are not to exceed 125 percent on a one-hour basis (State of Washington) or on a two-hour basis (State of Oregon). Since the states of Washington and Oregon have different TDG standards, the Corps will manage spill at the Lower Columbia and Snake River dams to the more stringent of the two.

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. Since 2006, both states have changed their methods for calculating the high 12-hour average. In November 2006, Washington Department of Ecology (WDOE) changed their method of calculating percent TDG to involve using a running consecutive 12-hour average. The daily high consecutive 12-hour TDG level is determined as the highest of the average value of each preceding 12-hour interval for each hour of the day. Oregon's revised method of calculating the "daily percent TDG" to an average of the 12 highest hourly readings in a given day for tailwater gauges only.

2.0 TDG Management

The TDG management measures differ depending on the category of spill, thus it is important to understand the definitions of voluntary and involuntary spill.

2.1 Voluntary and Involuntary Spill

There are two categories of spill: voluntary and involuntary. Voluntary spill occurs when spill is implemented in accordance with BiOp spill operations and applicable state water quality criteria. Voluntary spill is defined as the passing of water through the spillway gates of a dam to facilitate passage of juvenile salmon past the dam or passage of water to aid fish downstream migration. Spill at dams that pass juvenile salmonids decreases the residence time of juvenile salmon in the forebay of dams. Voluntary spill is also used at Dworshak Dam on the Clearwater River to provide for flow augmentation and to improve temperature conditions in the lower Snake River. The amount of voluntary spill is evaluated daily so that the resulting TDG levels associated with spill operations are consistent with the applicable state water quality criteria waiver or rule adjustment as described above. These TDG levels are referred to as "gas caps." The term "spill cap" is defined as the amount of spill necessary for TDG levels to reach the gas cap.

Involuntary spill occurs when hydrologic conditions result in flows which exceed the hydraulic capacity of power generation facilities. Involuntary spill is driven largely by local conditions at the dam (i.e. turbine capacity plus available storage is less than inflow). Other causes for involuntary spill include management of reservoirs for flood control, scheduled or unscheduled turbine unit outages of various durations, passing debris, or any other operational and/or maintenance activities required to manage dam facilities for safety and multiple uses.

2.2 Two Approaches to Managing TDG

There are two general approaches to TDG management: setting spill caps, and setting the order of dams to spill on the spill priority list.

- Values on the spill priority list serve as a reference for expected TDG production at the dams over a range of spill levels.
- There are times when not all of the units are operating at full capacity because there is insufficient market or demand for the energy and it becomes necessary to spill water. In these situations, TDG is managed by spilling according to the order provided on the spill priority list. During involuntary spill due to lack of market, there is the ability to move generation between dams, spilling at non-mainstem dams according to the spill priority list so that TDG is lower on the mainstem e.g. spilling 2 kcfs at Dworshak instead of 15 kcfs at Bonneville. This TDG management measure is implemented by initiating spill at dams according to the spill priority list by going from top-to-bottom, and left-to-right (see Table 1). The total amount spilled at any given dam will depend on the magnitude of the lack of market condition and will vary hourly.

Since TDG spill caps are important in managing TDG, this plan provides detailed explanations of why and how the spill caps are set.

2.2.1 Setting Spill Caps

The Corps Reservoir Control Center (RCC) Water Quality Unit sets the daily spill caps with the objective of operating consistent with applicable state TDG standards, reduce incidental take, reduce unsafe TDG levels in shallow areas, protect and limit damage to the physical dam structures, and minimize TDG production.

2.2.2 Spill Caps

The NMFS 2010 Supplemental BiOp and the 2011 Fish Operations Plan (Spring and Summer) call for the Corps to provide spill for fish passage on the lower Columbia and lower Snake Rivers up to the State water quality waiver and rule adjustment limits. Table 1 summarizes the initial spill caps and spill priority for managing spill. The spill caps are updated as needed based on real-time TDG information.

Table 1. Initial Spill Caps (kcfs) for 2011

Project	Spill Cap (KCFS) to Maintain %TDG Within Each Limit					
	110%	115%	120%	125%	130%	135%
LWG	20	30	41	90	125	200
LGS	10	15	32	80	110	250
LMN	10	15	31	55	110	250
IHR	30	45	95	125	135	240
MCN	40	80	145	230	290	450
JDA	20	60	120	240	300	600
TDA	20	60	125	250	260	600
BON	50	65	100	150	250	270
CHJ	19	50	100	160	160	160
GCL - outlet tubes	0	5	10	20	35	50
GCL - drum gates	0	20	40	75	120	130
DWR [a]	37%	42%	50%	60%	70%	75%

a. Dworshak spill caps are expressed as a percentage of total project discharge and represent an average of what the project can spill while maintaining %TDG within each limit. The actual percentage of project discharge that can be spilled for each %TDG limit may vary depending on real-time conditions.

2.2.3 Spill Order on the Spill Priority List

Since the project order for spilling listed on the *Spill Priority List* is important for managing TDG levels or when spill occurs due to lack of load, the spill order must be established before the high flows occur which is usually in mid-May. Before the beginning of spill season on April 3, RCC prepares an initial *Spill Priority List* based on the factors listed below. This list may be revised during the spill season depending on the location of the fish, research, river conditions and other circumstances. The spill priority lists are discussed in the TMT and revised accordingly.

When establishing the order of which dams should spill first, the following factors are considered:

- Location of Fish: If TDG levels are at or below 120 percent with high involuntary spill, the dams with the most fish are listed first on the priority list so the most fish are benefited with the high spill and flows.
- Location of High TDG: When TDG levels are above 120 percent with high involuntary spill, the dams with the most fish are listed last on the priority list so the least fish are harmed with the high spill and flows.
- Location of Fish Research: When fish research is planned or in progress, those dams are low on the priority list so the studies can remain intact as designed.
- River Reaches: Dams are considered in one of three blocks: Lower Snake; Lower Columbia and Middle Columbia. For example, if several Lower Snake dams need to be moved to low priority on the list, then the whole block of dams (LWG, LGS, LMN and IHR) are moved to the last on the list.

- Special Operations: Dams with special operations such as construction, maintenance or repair are placed last on priority list.
- Collector Dams: During low flow years, the collector dams (LGS, LWG, LMN, and MCN) are placed low on the priority list.
- Special Fish Conditions: If there are special fish conditions, such as disease or a special release, the dam is moved to first place on the priority list so the fish receive the maximum spill.

3.0 Process for Setting Spill Caps

This section provides a detailed explanation of how spill caps are set. There are several steps involved in setting daily spill caps, including evaluating SYSTDG simulations, review results and discuss proposed spill caps internally and with NOAA Fisheries.

3.1 Factors That Determine Spill Caps

The determination of spill caps at each individual dam is dependent upon an array of variables:

- SYSTDG Model: The SYSTDG model is used as a real-time operations tool to forecast the TDG production levels for all the dams with the assumption that the following day conditions will be the same as the current day. With these model results and information obtained from the other factors listed above, a new spill cap can be determined.

- Spill Operations: Fish spill operations for the dams are included in the Biological Opinion subject to adaptive management. These spill operations can be a percent of the total river flow, a flat spill rate, or spill to the spill cap. The spill operations are among the most influential factors for determining the spill caps.

- High 12-Hour Average TDG Reading: A review of the previous day's high 12-hour average TDG reading of the dam forebay and tailwater fixed monitoring station (FMS) is used to indicate whether the spill caps needs to be increased or decreased. The high 12-hour average TDG readings are among the most influential factors for determining the spill caps.

- Web Reports Used in Spill Review: The Corps has developed many web reports that summarize dam and water quality data, which are used in spill review and spill cap change decisions as follows:
    a. A program that calculates the amount of BiOp voluntary spill compared to how much BiOp voluntary spill actually occurred
    b. A report that calculates the percentage of spill at certain dams
    c. Data on flow, generation, spill, forebay elevation, TDG levels, and water temperature
    d. Tributary data for the Columbia River Basin
    e. Unit generation and spill bay data
    f. Water temperature string data

g. 10-day flow forecasts for the lower Columbia and Snake rivers

- Physical Design and Characteristics of Dams: TDG levels that are generated in the tailwaters of each dam depend upon many factors including the amount of spill passing through the spillway, the pattern of spill through the spillway, the amount of flow through the powerhouse, structure of the stilling basin, the presence (or absence) and elevation of flow deflectors, the presence (or absence) of divider walls, and river characteristics immediately below each dam. These individual characteristics are taken into account when assigning spill caps.
- Travel Time: The time it takes water to move from one dam to the next depends upon the distance between dams and the flow rate in the river. Because of this, changes in spill at an upstream dam and the resulting change in TDG levels will not be seen in the forebay of the downstream dam for several hours or days.
- Water Temperature: Climatic conditions can cause increases in water temperatures, which in turn can cause increases in TDG levels. The rule of thumb for water temperature is that a $1^{o}C$ ($1.8^{o}F$) increase in water temperature can result in a 2 to 3 percent increase in TDG. The impact of changing climactic conditions on water temperature is difficult to predict so air temperature is used as a surrogate. If it is expected that significant increases in air temperature are expected in a specific region, then it will be assumed that water temperatures would also be increasing and spill caps will be adjusted appropriately.
- Degassing: As waters flow from one dam to another, degassing can occur. Experience has shown that winds above 10 mph enhance degassing. Therefore, wind conditions (in combination with other ambient conditions) are used to predict levels of degassing and are included in the SYSTDG model used to determine daily spill caps. In addition, with flows below 200 kcfs, significant degassing of TDG occurs in the river between the Bonneville Dam and the Camas/Washougal FMS. However, when flows increase above 200 kcfs, little or no degassing has been observed.
- Flow Variations: Spill decisions are often affected by forecasts of river flows. Also, there are variations in flow on a weekly basis. On weekends, demand for power typically drops as compared to during the workweek, so flows may drop on weekends.
- Maintenance and Repairs: During an average spill season, there are many units that are out of service for various reasons. Scheduled maintenance and repair activities will reduce the amount of powerhouse capacity of a dam. The type of maintenance and repair activity and how it will affect flows through the dam is taken into account in order to assign appropriate spill caps.
- Experimental Test Schedules: The scheduling of various investigative studies can result in alterations in the normal operation of a dam. Examples of such alterations including modified spill pattern tests, removable spillway weir tests, and modified spill operations (e.g. at Ice Harbor, 50 percent spill operations for 24 hours for two days and then BiOp spill operations for the next two days).
- Minimum Spill: During low flow conditions, there are minimum voluntary spill discharge at Ice Harbor (15.2 kcfs); 25 percent at John Day and at Bonneville (75 kcfs).

- Minimum Generation: A minimum amount of flow for power generation is needed for electrical grid stability. During low flows, the minimum generation requirement will limit the spill rate from dams.
- Definition of Daytime and Nighttime: The definition of daytime and nighttime effects how long the spill level is maintained so a spill cap can be set a little higher knowing that it will be in effect for only a few hours. This factor is especially true for Bonneville where the definition changes frequently throughout the spill season.

3.2 How Daily Spill Caps Are Set

Spill caps are set for each dam and are adjusted daily or as needed, depending on actual TDG readings and the variability of the factors that determine spill caps listed in Section 3.1. These factors are reviewed daily and spill cap adjustments are made daily to ensure that TDG concentrations are consistent with state water quality criteria. The following is a more detailed description of how the spill caps are adjusted and set:

Step 1- Review Data: The various web reports that show flow forecast, weather forecast, flow, spill, generation, forebay elevation, unit outage information and water quality data are reviewed. The previous day data in terms of the determinant factors are compared against the ESA operation requirements. When there are discrepancies between actual spill and expected spill, RCC Water Quality Unit investigates the causes.

Step 2 - Investigation of Discrepancies: When there are discrepancies between actual spill and expected spill, RCC Water Quality staff coordinate with the following:

a. Unit Outage Coordinator – Are there unit or line outages occurring that are effecting spill operation? If there are, how many units or lines are down and how long, will it be until they return to service?

b. Fish Biologist – Sometimes there are special fish research operations or special fish operations that RCC Water Quality staff needs to be informed about.

c. Control Room Operators – RCC Water Quality staff discusses spill operations discrepancies to find out the reason. Based on this information, RCC Water Quality staff will need to talk to either Unit Outage Coordinator or the Fish Biologist.

Step 3 - Document Spill Review: As RCC Water Quality staff performs Step 2 data review, the spill change decision is documented to identify what type of TDG exceedance occurred, the current spill cap, which dams need to have their spill caps changed, the rational for the spill cap change, spill and flow ranges and what are the new proposed spill caps. The spill change decision form documents the results of the data review and the final decisions that were made on spill caps.

Step 4 - Run SYSTDG Model: RCC Water Quality staff checks the proposed spill caps with what the SYSTDG model suggest. It may be necessary to run several simulations until the right spill caps for all of the dams are obtained since a change at one location effects the next one downstream.

Step 5 - Spill Cap Change Discussion: The RCC Water Quality staff who performed Step 2 data review discusses the SYSTDG model results and data review findings. Typically the team members negotiate to reach an agreement on what the new spill caps should be.

Step 6 - Comments from NOAA Fisheries: The final completed spill change decision form is faxed to NOAA Fisheries water quality/spill specialist by 10:00 to allow them time to review spill decisions. RCC Water Quality staff waits until 12:00 for their comments about our proposed spill cap changes. If the NOAA Fisheries representative has questions or wants to discuss or negotiate changes to the spill caps, a RCC Water Quality staff answers their questions, negotiates, and resolves technical issues with the NOAA Fisheries representative. All questions and issues that are non-technical and are policy in nature are referred to the RCC Chief. Final spill caps will be sent out once the RCC Chief and the NOAA Fisheries representative reach an agreement.

Step 7 - Submit the New Spill Priority List: RCC Water Quality staff calls BPA real-time scheduling and the Control Room Operator to inform them that a new spill priority will be sent out with the new spill cap. RCC Water Quality staff sends out the new spill priority list with the new spill caps by 13:00.

4.0 TDG Management Policies

The highlights of the 2012 TDG Management policies are as follows:

- Manage dam operations to the extent practical in accordance with CWA and state water quality standards, modified through waivers and rule adjustments.
- Provide voluntary spill for fish consistent with the 2012 Fish Operations Plan.
- Dams will be operated to their authorized purposes.
- Voluntary spill policies will be as follows:
    a. Flows will be regulated to maximize potential for voluntary spill.
    b. Experiment with promising new spill patterns.
    c. Discontinue or postpone field research and non-critical unit service and maintenance schedules that create (or have potential for creating) high localized TDG levels, especially when and where high numbers of listed fish are present.
    d. Spill to improve juvenile fish passage while avoiding high TDG supersaturation levels or adult fallback problems. Specific spill levels will be provided for juvenile fish passage at each dam that will be consistent with applicable State TDG criteria.
    e. When dam voluntary spill occurs, the dams will be operated to manage TDG consistent with waiver or rule adjustment criteria without jeopardizing flood control objectives.
    f. Accommodate special spill requirements/restrictions for research, adult passage, etc. that have the full endorsement of all concerned parties.
- Involuntary spill policies will be as follows:
    a. When possible, the Corps will manage involuntary spill to minimize TDG production as described in section 2.2.3.
    b. Implement the spill priority discussed in Sections 2.0 and 3.0. Spill will start as specified in the Spill Priority List unless and until a different priority is recommended by the TMT.

The management of spill at each dam is based on TDG levels measured at specific forebay and tailwater FMS. The current locations of these gauges are based on extensive studies that have been conducted since 1996. The Corps will continue to coordinate with the States of Oregon and Washington on voluntary spill for fish passage, and provide technical information to inform the process. Future spill operations may be modified through the implementation planning process and adaptive management. The Corps' decision on the spill program will consider water quality effects along with the results of spill studies, biological evaluations, and the relationship to achieving BiOp performance standards.

5.0 TDG Monitoring Program

In support of the spill management program, a TDG monitoring program has been established and is described in the Dissolved Gas Monitoring Plan of Action. This monitoring program is revised to include changes in the FMS system and evaluated by regional representatives.

A copy of the 2011 Dissolved Gas Monitoring Plan of Action can be obtained from the RCC Water Quality Programs webpage, Dissolved Gas and Water Temperature Monitoring Report, 2011, Appendix B found at: http://www.nwd-wc.usace.army.mil/tmt/wqnew/