Appendix 4

2013

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 voluntary and involuntary spill, use of the spill priority list, the process for setting spill caps, TDG management policies, and the TDG monitoring program. This Plan is consistent with the 2000 U.S. Fish and Wildlife Service (USFWS) Biological Opinion, and the NOAA Fisheries 2010 Supplemental Biological Opinion (2010 Supplemental BiOp)[1].

1.1 Background

During the 1990s, Snake and Columbia River salmonids were listed under the Endangered Species Act (ESA). Through ESA consultations, the Corps implemented a variety of operational and structural measures that were called for in biological opinions to improve the survival of listed salmonids. The 2010 Supplemental BiOp calls for the Corps to provide spill for juvenile fish migration in the Federal Columbia River Power System (FCRPS). The Action Agencies annually develop a Fish Operations Plan (FOP) that provides detailed information on the implementation of the BiOp fish passage operations.

1.2 State Water Quality Standards

The Federal Clean Water Act establishes the aquatic life criteria for TDG of 110 percent that have been adopted by the four states and regional tribal governments. The states of Washington and Oregon have authorized exceptions (rule adjustment and waiver, respectively) to these standards as long as the elevated TDG levels provide for improved fish passage without causing more harm to fish populations than through other passage routes.

The five year 2010-2014 Oregon TDG waiver specifies that from April 1 through August 31 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. The five year 2010-2014 Washington rule adjustment specifies that in order to aid fish passage TDG levels are not to exceed either 120 percent in the project tailwater or 115 percent in the forebay of the next downstream dam. This is measured as the average of the twelve highest hourly (consecutive) readings in any one day. The criteria 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).

Changes made to these state water quality standard exceptions in recent years have not been fully applied because the Corps is operating under a Court Order to continue spill for juvenile fish as implemented in 2006 through 2012. The Corps continues to use the Camas Washougal water

[1] The 2010 Supplemental BiOp incorporates the 2008 NOAA BiOp.

quality monitoring station and calculates the 12-hour average based on the twelve highest hourly reading in any one day.

2.0 Voluntary and Involuntary Spill

TDG management measures differ depending on whether the spill occurring at Corps and Reclamation dams is voluntary, i.e. spill for the benefit of juvenile fish migration through the FCRPS; or involuntary, i.e. spill that is dictated by conditions beyond the Corps' control and require implementation of measures to manage TDG levels given these conditions. The following describes circumstances that result in various types of spill.

Voluntary Spill or Fish-passage spill occurs for the benefit of juvenile fish migration in accordance with the operative biological opinions. The 2010 Supplemental BiOp recommends the Corps and BPA provide specific spill levels to improve juvenile fish passage, and not exceed applicable state water quality standards for TDG. At some Corps projects, the amount of voluntary spill is a specified level, and at others the Corps is to spill up to the applicable state TDG criteria -- referred to as the "gas cap." The maximum project spill level that meets but does not exceed the gas cap is referred to as the spill cap.

Involuntary Spill - Spill for reasons other than the benefit of juvenile fish migration is referred to as "Involuntary Spill." Involuntary spill is driven largely by hydrologic capacity at each dam; the quantity of water that exceeds the capacity of a dam to either temporarily store the water upstream of the dam or pass the water through its turbines. In these circumstances, water must be released through the spillway. The following are conditions that may result in involuntary spill:

- **Lack-of-Turbine Spill** occurs when flows exceed the hydraulic capacity of the available power generation facilities at a specific dam. Lack of turbine spill can also be affected by planned and unplanned unit outages, planned and unplanned transmission outages and other transmission constraints. Any of these conditions physically limit the potential for hydropower production. Lack-of-turbine spill will generally be the amount of river flow in excess of the maximum amount that can be released through all available generators and other outlet structures (e.g. sluiceways, fish ladders, etc.). In general, when this condition occurs, the affected project will be operating at maximum generation capability to minimize the amount of spill. Lack-of-turbine spill can also occur when BPA must provide mandatory reserve power capacity (reserves) for contingencies and load balancing. Reserves are the amount of generation capacity above the amount currently in use that is immediately available when needed to maintain system reliability. At projects that must carry reserve power capacity, these projects can only be loaded to the maximum available generation minus the reserve capacity allocated to that project. Spill for maintaining reserves primarily occurs at Grand Coulee, Chief Joseph, The Dalles, John Day, Bonneville and occasionally McNary. Information from the Spill Priority List is used to guide where and to what extent BPA allocates reserves to the various projects and other actions that may limit system reserve obligations.

- **Lack-of-load spill** occurs when the available market for hydropower is less than the power that could be produced by the current river flow with available turbine capacity. When BPA

does not have a market to sell hydropower, the river flow must be released over the spillway. Lack-of-load spill generally occurs during times of high flows (e.g., in the spring or fall when power demands are low both in California and the Pacific Northwest). Also releases from upstream storage dams during high load times of the day (morning and evening) can result in high flows at downstream dams during low load times of the day (middle of the night), causing lack-of-load spill. Lack-of-load spill is managed on a system-wide basis to distribute TDG levels across the Federal projects using the spill priority list (Section 3) as compared to. lack-of-turbine spill which is project specific.

- **Miscellaneous spill** – Spill occurs occasionally for other reasons, for example, spill to pass debris or for safety reasons. These are infrequent and generally short duration.

3.0 Spill Priority List

Spill priority lists are primarily used to manage system-wide TDG levels and are used throughout the year. Spill priority lists may also be utilized to inform other decisions such as how to allocate reserves to the projects or manage other system obligations. The Corps' Reservoir Control Center (RCC) prepares spill priority lists based on the factors described in section 3.2, and revisions are discussed in the Technical Management Team (TMT) meetings as appropriate.

3.1 Spill Levels

Values on the spill priority list serve as a reference for expected TDG production at the dams and are applicable for all spill conditions. Estimated spill rates are grouped into different TDG production levels (spill cap targets) on the spill priority list as shown below:

- Voluntary Spill– Target spill levels as described in the Fish Operations Plan (FOP) for fish passage
- Level 1 - Spill flows up to 120 percent TDG in the project tailrace or 115 percent TDG in the next downstream forebay (whichever is less)
- Level 2 – Spill flows up to 120 percent TDG in the project tailrace
- Level 3 – Spill flows up to 122 percent TDG in the project tailrace
- Level 4 – Spill flows up to 125 percent TDG in the project tailrace
- Level 5 – Spill flows up to 127 percent TDG in the project tailrace
- Level 6 – Spill flows up to 130 percent TDG in the project tailrace
- Level 7 – Spill flows up to 135 percent TDG in the project tailrace

3.2 Factors for Setting Spill Priority

When establishing the order dams will spill above that required for BiOp juvenile fish passage, the following factors are considered:

- Location of Fish: Location and number of adult and juvenile fish in the migratory corridor is a factor in establishing the spill priority order on the spill priority list.

- Location of High TDG: When TDG levels are elevated (above 120 percent) dams may be shifted on the list to manage system-wide TDG levels.
- Location of Fish Research: When fish research is planned or in progress, those dams are low on the priority list to minimize detrimental impact to the studies.
- River Reaches: Dams are considered in one of three blocks: the lower Snake River, the lower Columbia River, and the middle Columbia River. For example, if several of the lower Snake dams need to be moved to a lower priority on the spill priority list, then the whole block of dams (Lower Granite, Little Goose, Lower Monumental and Ice Harbor dams) may be moved to last position 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 (Lower Granite, Little Goose, Lower Monumental and Ice Harbor dams) 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 may be moved higher or lower on the priority list depending on circumstances.
- System-wide TDG management: Grand Coulee, Chief Joseph, Dworshak and other projects are included on the spill priority list to help balance system-wide TDG levels during periods of involuntary spill.

4.0 Process for Setting Spill Caps

The Corps RCC Water Quality Unit develops daily spill caps[2] for Corps projects with the objective of attaining the BiOp/FOP spill levels consistent with applicable TDG standards, and managing system-wide TDG levels during involuntary spill consistent with the spill priority list. Spill caps may vary depending on flow, spill operation, spill pattern, temperature, and other environmental conditions.

The following provides a detailed explanation of the steps involved in setting daily spill caps, including evaluating SYSTDG simulations, reviewing results and discussing proposed spill caps internally and with NOAA Fisheries.

4.1 Factors Considered in Setting Spill Caps

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

1. FOP Spill Operations: The voluntary spill released from the projects as prescribed in the BiOp and specified in the Fish Operations Plan (FOP). These are the baseline spill flow rates in the lower Snake and lower Columbia rivers. These spill operations can be a percent of total river flow, a fixed level, or up to either the 120 percent TDG (tailwater) or the 115 percent TDG (forebay) "gas cap," whichever is less.

[2]. The spill cap is the estimated spill rate to achieve the appropriate level of spill to meet state TDG gas cap levels or to meet target levels of TDG identified in the Spill Priority List (See Section 3.1).

2. 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 need to be increased or decreased.

3. Data Reports Used in Spill Review: The Corps has developed many reports that summarize various dam operations, river flows, and water quality data considered in spill review and adjustment decisions as follows:
    a. Calculation of the amount of BiOp voluntary spill compared to how much BiOp voluntary spill actually occurred
    b. Calculation of the percentage of spill at certain dams
    c. Data on flow, generation, spill, forebay elevation, TDG levels, and water temperature at each dam
    d. Tributary flow and temperature data for the Columbia River Basin
    e. Unit generation and spill bay data for each dam
    f. Water temperature string data at each dam
    g. 10-day flow forecasts for the lower Columbia and Snake rivers
    h. Wind forecasts for the lower Columbia and lower Snake rivers

4. 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.

5. 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.

6. 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 climatic conditions on water temperature is difficult to predict so air temperature is used as a surrogate. If a significant increase in air temperature is expected in a specific region, then it is assumed that water temperatures will also be increasing and spill caps will be adjusted appropriately.

7. 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 fixed monitoring station (FMS). However, when flows increase above 200 kcfs, little or no degassing has been observed.

8. Flow Variations: Spill decisions are often affected by forecasts of river flows which vary on a weekly basis.

9. Power Demand: On weekends, demand for power typically drops as compared to during the workweek, so flows may drop on weekends.

10. 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.

11. 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.

12. Minimum Spill: During low flow conditions, minimum voluntary spill discharges are defined in the FOP, e.g. 25 percent at John Day and 50 kcfs at Bonneville.

13. 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.

14. Definition of Daytime and Nighttime: The definition of daytime and nighttime hours affects the duration of certain spill levels. Due to shorter nights during summer, a spill cap can be set a little higher, recognizing that it will be in effect for only a few hours.

4.2 Setting Daily Spill Caps

Spill caps are reviewed daily for each dam and are adjusted as needed, depending on actual TDG readings and the variability of the factors considered when determining spill caps listed in Section 3.1. The following is a more detailed description of how the spill caps are adjusted and set:

Step 1-Review Data: The various data reports that show flow forecast, weather forecast, flow, spill, generation, forebay elevation, unit outage information and water quality data are reviewed. The previous day's data, in terms of the determinant factors, are compared against the spill operation requirements at each dam.

Step 2-Investigation of Spill Variances: When there are variances between actual spill and expected FOP spill, RCC Water Quality staff investigates the causes by contacting 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 – Are there any research operations or special fish operations that may have caused the variance?
C. The Control Room Operators –Staff also contacts the operator on duty at a given dam to help determine what might have caused the variance.

Step 3-Document Spill Review: Each day, RCC Water Quality staff performs a spill data review and documents on the daily spill decision form the current river flow, spill and operations at each dam, current spill caps, dams that need modified spill caps to maximize spill while maintaining TDG levels, the rationale for the spill cap change and the proposed spill caps in preparation for using SYSTDG model.

Step 4-Run SYSTDG Model: The SYSTDG model may be used as a real-time operations tool to forecast the TDG production levels for all the dams. RCC Water Quality staff checks the proposed spill caps with the SYSTDG model results. It may be necessary to run several simulations until the appropriate spill caps for all dams are determined since a change at one location affects the next one downstream.

Step 5-Spill Cap Determination: The RCC Water Quality staff uses the data review and model results to determine the spill caps based on their best professional judgment and documents any proposed changes and the final decisions related to spill caps in the daily spill decision form.

Step 6-Comments from NOAA Fisheries: The final completed daily spill decision form is sent to NOAA Fisheries water quality/spill specialist by 1000 hours to allow them time to review spill decisions. If the NOAA Fisheries representative wants to discuss potential changes to the proposed spill caps, a RCC Water Quality staff is available to answer questions and resolve technical issues. Any question or issue that raises policy issues are referred to the RCC Chief. Spill caps are finalized once the RCC Chief (or their representative) and the NOAA Fisheries representatives reach 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 list will be sent out with the new spill caps. RCC Water Quality staff sends out the new spill priority list with the new spill caps by 1400 hours.

5.0 TDG Management Policies

The Corps will consider water quality effects along with the results of spill studies, biological evaluations, the relationship to achieving BiOp performance standards and incorporate the following TDG management policies in its decision making:

- 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 applicable biological opinion requirements while avoiding high TDG levels or adult fallback problems. Specific spill levels will be provided for juvenile fish passage at each dam consistent with applicable State TDG criteria or applicable waiver or rule adjustment criteria.

- Operate dams to the authorized project purposes.
- Regulate flows to maximize potential for voluntary/fish passage spill.
- Discontinue or postpone 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.
- Accommodate special spill requirements/restrictions for research, adult passage, etc. that have been coordinated with the TMT.
- Manage the system in coordination with the Bureau of Reclamation and BPA to avoid involuntary spill and minimize TDG production when possible, without jeopardizing flood control objectives.
- Implement the spill priority list discussed in Section 3.0.

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.

6.0 TDG Monitoring Program

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.

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 2010 – 2014 Dissolved Gas Monitoring Plan of Action can be obtained from the RCC Water Quality Programs webpage, Dissolved Gas and Water Temperature Monitoring Report, 2012, Appendix B found at:

http://www.nwd-wc.usace.army.mil/tmt/wqnew/tdg_and_temp/2012/app_b.pdf