2006 Total Dissolved Gas Management Plan

1.0 Introduction

High total dissolved gas (TDG) saturation levels are observed in various parts of the Columbia and Snake River systems where spill occurs, sometimes creating conditions that may adversely affect fish survival. Therefore, a plan to control TDG is developed annually along with a water management plan based on the runoff and the resulting spill for that year. This document outlines the TDG management plan adopted by the Technical Management Team (TMT) for 2006. It includes a review of voluntary and involuntary spill, applicable management options, and a detailed TDG management plan with spill priority list and spill caps. This plan reflects relevant provisions of both the U.S. Fish and Wildlife Service and the National Marine Fisheries Service (NMFS) Federal Columbia River Power System (FCRPS) Biological Opinions (BiOps).

2.0 Voluntary and Involuntary Spill

2.1 Voluntary Spill

Voluntary spill is defined as the passing of water through the spillway gates of a dam to facilitate passage of juvenile salmon past the project. This operation is done to decrease the residence time of juvenile salmon in the forebay of dams, which increases their passage and survival in the FCRPS. Spill, as a fish passage strategy, has a higher survival rate than most other routes of passage at the dam. The amount of voluntary spill is adjusted so that the resulting TDG levels associated with spill are consistent with applicable State water quality criteria.

Another reason for spill is for flow augmentation. The NMFS and USF&WS BiOps call for flow augmentation in the Columbia and Snake Rivers. There are instances where spill at some projects is required to obtain the flow objectives called for in these BiOps.

2.2 Involuntary Spill

Involuntary spill is caused primarily by project and/or system operational limitations. There are two primary causes for involuntary spill:

1. When hydrologic conditions results in flows which exceed the hydraulic capacity of power generation facilities, and

2. When potential power generation from above average water supplies exceeds the available market, especially during light market hours at night and on weekends.

Other causes for involuntary spill includes 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 project facilities. For example, in managing the project for flood control, the water supply forecast may underestimate the seasonal streamflows and cause the project operators to leave too little space in the reservoirs to catch the water. In other instances, unusually high winter precipitation may force the operators to store

water in the reservoirs above the flood control elevations, causing involuntary spill to occur later as the water is evacuated to get to the reservoir flood control elevations.

The anticipated frequency and extent of involuntary spill due to hydrologic conditions cannot be predicted until the 2006 (April Final) January through July forecast for the Columbia River at The Dalles is completed. Isolated instances of involuntary spill, prompted by scheduled or unscheduled turbine unit outages of various durations and/or other operational and maintenance activities, are expected to occur in 2006.

3.0 Management Options

3.1 2006 Fish Passage Implementation Plan Spill Guidance:

On May 26, 2005, U.S. District Court James A. Redden invalidated the 2004 BiOp. On October 7, 2005 he remanded the FCRPS BiOp back to NOAA Fisheries to re-write by October 2006. In the interim, he ordered the 2004 Biological Opinion remain in effect. He also ordered the re-write to be done collaboratively with sovereigns which include the states of Idaho, Montana, Oregon, Washington and Nez Perce, Umatilla, Yakima, Warm Springs and Kootenai Tribes. On December 29, 2005 the court granted the plaintiffs a preliminary injunction which provided for fish passage operations (including spill) different than the 2004 BiOp. The COE submitted a 2006 Fish Passage Implementation Plan on April 3, 2006 to the court, which incorporated the operations included in Judge Redden's December 29, 2005 Preliminary Injunction Opinion and Order. This plan is an addendum to the 2006 Water Management Plan. Below is a description of the voluntary spill regimes specified in the 2006 Fish Passage Implementation Plan. Table 1 provides a summary of the operations.

Lower Granite Dam: Voluntary spill will begin at Lower Granite Dam at 0001 hrs on April 3rd and will end at 2400 hrs on August 31st. Voluntary spill during the spring (April 3 through June 20) will consist of 20 kcfs spill using the removable spillway weir (RSW). This spill entails passing approximately 6 kcfs through the RSW and the remaining 14 kcfs through other spill gates as "training spill." Summer voluntary spill (June 21 through August 31) will consist of 18 kcfs spill using the RSW. This spill entails passing approximately 6 kcfs through the RSW and the remaining 12 kcfs through other spill gates as "training spill." Both spring and summer spill regimes will occur 24 hours per day but may be limited by the 120% Lower Granite tailwater gas cap or the 115% TDG gas cap in downstream forebays. The firm generation commitment for this project is 11.5 kcfs. However, this minimum depends on the status of generation at other projects and may not be necessary at all times.

Table 1. Spill Guidelines at Lower Columbia and Snake River projects.

Project	Planning Dates	Time	Amount [c]	Minimum Generation Requirements kcfs
Lower Granite	April 3 - June 20	24 hours per day	20 kcfs (RSW with training)	11.5 [a]
Lower Granite	June 21 - August 31	24 hours per day	18 kcfs (RSW with training)	11.5 [a]
Little Goose	April 3 - August 31	24 hours per day	To the spill cap up to 30% of project outflow	11.5 [a]
Lower Monumental	April 3 - June 20	24 hours per day	To the spill cap up to 40 kcfs	11.5 [a]
Lower Monumental	June 21 - August 31	24 hours per day	To the spill cap up to 17 kcfs	11.5 [a]
Ice Harbor	April 3 - August 31	500 - 1800	45kcfs	7.5 - 9.5 [a]
Ice Harbor	April 3 - August 31	1800 - 500	To the spill cap	7.5 - 9.5 [a]
Ice Harbor	TBD	24 hours per day	spill will alternate between to the spill cap up to 30% of project outflow and 45kcfs daytime/spill cap at night [b]	7.5 - 9.5 [a]
McNary	April 10 - April 22	24 hours per day	0 kcfs daytime/To the spill cap (~150 kcfs) at night	49
McNary	April 23 - June 20	24 hours per day	spill will alternate between 40% and 0 kcfs daytime/To the spill cap (~150 kcfs) at night [b]	50
McNary	June 21 - June 30	500 - 1800	0	50
McNary	June 21 - June 30	1800 - 500	To the spill cap or 150 kcfs	50
McNary	July 1 - August 31	24 hours per day	spill will alternate between to the spill cap or 40% and to the spill cap or 60% [b]	50
John Day	April 10 - June 20	600-1800	0	50
John Day	April 10 - May 15	1800 - 600 [e]	To the spill cap or 60 % of project outflow	50
John Day	May 15 - June 30	1900 - 600 [e]	To the spill cap or 60 % of project outflow	50
John Day	June 30 - August 31	24 hours per day	To the spill cap or 30% of project outflow	50
John Day	April 10 - August 31	24 hours per day	Minimum spill is 30% of project outflow	50
The Dalles	April 10 - August 31	24 hours per day	To the spill cap or 40% of project outflow	50
Bonneville	April 10 - June 30	24 hours per day	To the spill cap up to 100 kcfs	30
Bonneville	July 1 - August 31	daytime [d]	To the spill cap up to 75kcfs	30
Bonneville	July 1 - August 31	nighttime [d]	To the spill cap (~120 kcfs)	30
Bonneville	April 10 - August 31	24 hours per day	minimum spill is 50 kcfs	30

a - Minimum generation requirements at the Lower Snake Riverprojects may not be needed all the time.
b - There is a fish test occurring at this project. See Fish test section
c- Spill cap is defined as the maximum spill amount that will keep the High 12 hr %TDG average within the State WQ standards of 115% in the forebay or 120% in the tailwater
d- Day and nighttime for Bonneville vary during the spill season and are set in the Fish Passage Plan.
e- Day and nighttime for John Day usually changes on May 15 but this is not stated in the court order, General Martin's

Little Goose Dam: Voluntary spill will begin at Little Goose Dam at 0001 hrs on April 3rd and will end at 2400 hrs on August 31st. For both spring and summer seasons, spill at Little Goose will consist of spilling to the 120% Little Goose tailwater gas cap or the 115% TDG gas cap in downstream forebays up to 30% of total project outflow 24 hours per day. The firm generation commitment for this project is 11.5 kcfs. However, this minimum depends on the status of generation at other projects and may not be necessary at all times.

Lower Monumental Dam: Voluntary spill will begin at Lower Monumental Dam at 0001 hrs on April 3rd and will end at 2400 hrs on August 31st. Voluntary spill during the spring (April 3 through June 20) will consist of spilling to the 120% Lower Monumental tailwater gas cap or the 115% TDG gas cap in downstream forebays up to 40 kcfs 24 hours per day. Summer voluntary spill (June 21 through August 31) will consist of spilling to the 120% Lower Monumental tailwater gas cap or the 115% TDG gas cap in downstream forebays up to 17 kcfs 24 hours per day. The firm generation commitment for this project is 11.5 kcfs. However, this minimum depends on the status of generation at other projects and may not be necessary at all times.

Ice Harbor Dam: Voluntary spill will begin at Ice Harbor Dam at 0001 hrs on April 3rd and will end at 2400 hrs on August 31st. Voluntary spill during both the spring seasons will consist of spilling 45 kcfs during the daytime (0500 to 1800 hrs) and to the spill cap at night (1800 hrs to 0500 hrs). During this spill season, research studies are planned where spill will alternate between the normal spring operations described above and an operation that consists of spilling to the Ice Harbor tailwater 120% TDG gas cap or to the 115% TDG gas cap in downstream forebays up to 30% of total project flow in a bulk spill pattern 24 hours per day. During both spill operations, the RSW at Ice Harbor will be utilized. When the studies are being conducted, spill regimes will alternate between the two operations. The specific details of the study and the schedule of spill regimes will be provided at a later date. The firm generation commitment for this project is 11.5 kcfs. However, this minimum depends on the status of generation at other projects and may not be necessary at all times.

McNary Dam: Voluntary spill will begin at McNary Dam at 0001 hrs on April 10th and will end at 2400 hrs on August 31st. Voluntary spill during the spring spill season (April 10 through June 30) will consist of spilling 0 kcfs during the daytime (0500 to 1800 hrs) and to the spill cap at night (1800 hrs to 0500 hrs). During the spring season, a research study is planned where spill will alternate between the normal spring operations described above and an operation that consists of spilling to the McNary tailwater 120% TDG gas cap or to the 115% TDG gas cap in downstream forebays up to 40% of total project flow 24 hours per day. Voluntary spill during the summer spill season (April 10 through June 30) will consist alternating between spilling to the McNary tailwater 120% TDG gas cap or to the 115% TDG gas cap in downstream forebays up to 40% of project outflow and spilling to these gas caps up to 60% of project outflow 24 hours per day. The firm generation commitment for this project is 50 kcfs. However, this minimum depends on the status of generation at other projects and may not be necessary at all times.

John Day Dam: Voluntary spill will begin at John Day Dam at 0001 hrs on April 10th and will end at 2400 hrs on August 31st. Voluntary spill during the spring spill season (April 10 through June 30) will consist of spilling 0 kcfs during the day and to the John Day Dam tailwater 120% TDG gas cap or the downstream forebay 115% TDG gas cap up to 60% of project outflows during the night. Nighttime is defined as 1800 hrs to 0600 hours from April 10th to May 15th and from 1900 hrs to 0600 hours from May 16th to June 30th. Voluntary spill during the summer spill season (July 1 through August 31) is to spill to the John Day Dam tailwater 120% TDG gas cap or the downstream forebay 115% TDG gas cap or 30% of project flows 24 hours per day. Minimum voluntary spill at the project is 30%. The firm generation commitment for this project is 50 kcfs. However, this minimum depends on the status of generation at other projects and may not be necessary at all times.

The Dalles Dam: Voluntary spill will begin at The Dalles Dam at 0001 hours on April 10th and will end at 2400 hrs on August 31st. Voluntary spill during both the spring and summer seasons will consist of spilling to The Dalles Dam 120% tailwater TDG gas cap or the downstream forebay 115% TDG gas cap up to 40% of project outflows. The firm generation commitment for this project is 50 kcfs. However, this minimum depends on the status of generation at other projects and may not be necessary at all times.

Bonneville Dam: Voluntary spill will begin at Bonneville Dam on April 10th and will end on August 31st. Voluntary spill during the spring (April 10 to July 30) will consist of spill to the Bonneville tailwater 120% TDG gas cap (as measured at the Cascades Island (CCIW) FMS) or the 115% TDG gas cap at the Camas-Washougal (CWMW) FMS up to 100 kcfs 24 hours per day. Voluntary spill during the summer season will consist of spilling to the CCIW 120% TDG gas cap or to the 115% TDG gas cap at CWMW up to 75 kcfs during the day and to these gas caps at night. Nighttime hours at Bonneville dam changes several times throughout the spring and summer (see the 2006 Fish Passage Plan). Minimum voluntary spill at the project is 30%. The firm generation commitment for this project is 30 kcfs. However, this minimum depends on the status of generation at other projects and may not be necessary at all times.

3.2 Spill Management to the TDG Gas Caps:

Spill caps will be assigned to each project and will be adjusted in-season, based on actual TDG readings and a variety of other factors. TDG measurements will be reviewed on a daily basis and minor adjustments to the voluntary spill at each project will be made to the daily spill cap in order for TDG concentrations as close as possible, but not exceeding 120% in the tailraces and 115% in the forebays. The assignment of spill caps at each individual project is dependent upon an array of variables. Factors that are evaluated in the determination of spill caps are as follows,

1. Physical Design and Operation of Projects: TDG levels that are generated in the tailwaters of each project 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) of flow deflectors, the presence (or absence) of divider walls, the presence (or absence) of fish screens (which can influence decisions regarding distribution of spill at specific projects) , and river characteristics immediately below each project. These individual characteristics are taken into account when assigning spill caps.

2. Travel Time: The time it takes water to move from one project to the next depends upon the distance between projects and the flow rate in the river. Because of this, changes in spill at an upstream project and the resulting change in TDG levels will not be seen in the forebays of the downstream project for several hours or days.

3. 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% increase in TDG. Since the impact of changing climactic conditions on water temperature cannot be directly predicted, air temperature is used as a surrogate. If it is expected that significant increases 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.

4. River Characteristics: Characteristics of the river channel can influence TDG levels. For example, the forebay of Lower Monumental Dam is shallow and therefore susceptible to heating by sunlight. Other projects have forebays that are deeper, and therefore less susceptible to heating effects.

5. Degassing: As waters flow from one project to another, degassing can occur. Experience has shown that winds above 10 mph enhances degassing. Therefore, wind conditions are used to predict levels of degassing. In addition, 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.

6. Flow Variations: Spill decisions are often affected by forecasts of flows for the near future. For example, when high flows are anticipated, shifting of spill priorities at different projects may occur in order to develop an overall river-wide strategy to minimize TDG exceedances. Also, there are variations in flow on a weekly basis. On weekends, demand for power typically drops as compared to during the workweek. This results in decreases in flow through project powerhouses. As a result, the relative proportion of spilled water flow (which typically has higher TDG levels) to powerhouse flow (which typically has lower TDG levels) increases. If this condition is not taken into account, then tailwater TDG levels will be higher than what was predicted. The opposite occurs on Mondays where powerhouse flow generally increases over the flow on the weekends due to an increase in power demand as the workweek begins.

7. Maintenance and Repairs: Scheduled maintenance and repair activities can modify the amount of flow through a particular project. The type of maintenance and repair activity and how it will affect flows through the project need to be taken into account in order to assign appropriate spill caps.

8. Experimental Test Schedules: The scheduling of various investigative studies can result in alterations in the normal operation of a project. Examples of such alterations including modified spill pattern tests, Removable Spillway Weir tests, and modified spill operations (e.g. at Ice Harbor, 50% spill operations for 24 hours for two days and then BiOp spill operations for the next two days).

4.0 2006 TDG Management Plan

The 2006 TDG Management Plan is similar to previous years' plans. Storage reservoirs will be operated to flood control rule curves and are projected to provide some cushion that will minimize incidences of involuntary spill. No pre-emptive reservoir drafting below flood control elevation will be attempted, as the Salmon Managers are also concerned about reservoir refill. Flows will be regulated to maximize potential for voluntary spill. When project voluntary spill occurs, the projects will be operated to try to keep TDG at or below 120% as long as possible without jeopardizing flood control objectives. When TDG cannot be managed to 120%, the river will be managed in the best interest of listed and proposed salmon stocks. It is recognized that

measures designed to physically reduce TDG could have significant impact on migrating salmon. Therefore, input from state and tribal salmon managers and TDG will be sought when attempting to use those TDG control measures.

The essence of the 2006 TDG Management Plan (see Figures A-1 and A-2 in the Attachment at the end of this Appendix), which may be modified in-season by the TMT if necessary, is as follows:

- Implement spill for fish passage at all mainstem Federal dams as specified in the 2006 Fish Passage Implementation Plan (31 March 2006) up to the spill caps for 120% TDG in Mainstem project tailraces or 115% in the forebay of the next downstream project given in the Attachment at the end of this Appendix. Adjust spill as needed, based on real-time TDG data, and fish movement and biological conditions in that order.

- Operate unit operation within 1% of peak efficiency.

- Accommodate special spill requirements/restrictions for research, adult passage, etc. that have the full endorsement of all concerned parties. Also, continue to implement fish transportation program as agreed to and using calculation method endorsed by NMFS (or an equivalent method agreed to at TMT).

- If systemwide TDG exceed 120%, update and implement the spill priority outlined in Attachment 1, with incremental system TDG control objectives. Unless and until a different reach priority is recommended by the TMT, spill will start as specified in the Spill Priority List.

- 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.

- If regionally coordinated and approved by the TMT, operate turbines outside their respective 1% peak efficiency flow range at projects where measurable reduction in TDG (at least 3%, given the accuracy range of the instrumentation) and no intolerable adverse fish impacts can be expected.

- If regionally coordinated and approved by the TMT, store water at lower Snake reservoirs above MOP, if this would result in a measurable (3% or more, based on instrumentation accuracy) reduction in TDG levels.

- Experiment with promising new spill patterns.

- Implement other operations or measures recommended by the TMT or the IT. This may include appropriate changes in transportation targets when TDG exceeds levels that are universally recognized as lethal (130% more for 1 week or longer, per NOAA Fisheries) or when obvious in-river lethal conditions exist.

5.0 2006 TDG Monitoring Plan of Action

In support of the spill management program, a TDG monitoring program has been established. Each year, this monitoring program is evaluated by the Regional Forum Water Quality Team (WQT). The draft plan for 2006 was presented to the WQT at the November 2005 meeting and discussed at the December 2005 and January 2006 meetings. Based on discussions at these meetings and submitted written comments, the final plan for 2006 was completed in late January. A copy of this plan can be obtained at the TMT/Water Quality Programs webpage at http://www.nwd-wc.usace.army.mil/TMT/wqwebpage/mainpage.htm

6.0 TDG Modeling

Total Dissolved Gas caused by large volumes of water spilled over dams can result in injury and mortality of juvenile salmonids. Development and continued refinement of a systemwide TDG model would assist with in-season management of involuntary spill.

In response to RPA 133 of the NMFS 2000 Biological Opinion, the Corps began developing a TDG model to be used as a river operations management tool. During the 2004 spill season, this model (SYSTDG) was utilized on a trial basis to evaluate TDG in the Columbia River Basin and to assist in the setting of spill caps at each of the projects where voluntary spill occurred. At the conclusion of the spill season, a review of the performance of SYSTDG was completed and included in the 2004 Dissolved Gas and Water Temperature Monitoring Report. The same was done for the 2005 spill season. These reports are available on the TMT/Water Quality Programs webpage at http://www.nwd-wc.usace.army.mil/TMT/wqwebpage/mainpage.htm .

For the 2006 Spill season, SYSTDG will again be used as a TDG management tool. As the season progresses, modification of the model will occur as necessary due to modifications in project operations.

7.0 Temperature Management

The 2004 NOAA Fisheries Biological Opinion calls for cold-water releases from Dworshak reservoir. These releases serve the dual purpose of providing additional flows of water to assist passage of juvenile salmonids past the lower Snake River projects and to help moderate water temperatures of that water. The management of the temperatures of these release waters is possible due to the presence of selector gates at Dworshak Dam which can move vertically and draw water from varying elevations in the reservoir.

The management of the flows and water temperatures from Dworshak reservoir is coordinated with TMT. The Water Quality Unit (WQU) of the Corps' Reservoir Control Center will provide TMT with water temperature stratification data from the Dworshak reservoir as well as temperatures of release water derived from the Dworshak tailwater fixed monitoring station (DWQI). The WQU will also provide TMT with recommendations concerning the amount of storage of cool waters in the reservoir to ensure that these sufficient quantities will be maintained through mid-September and what outflow water temperatures will be expected when the operation concludes and the projects returns to minimum flows.

Attachment
SPILL PRIORITY LIST and SPILL CAPS (April 20 - August 31)

This attachment provides project priority for spill and allowable spill levels to be used in an attempt to control total dissolved gas (TDG) to 120%, 125%, 130% and 135%. When systemwide TDG is at or below 120%, provide spill for fish passage on the Lower Columbia and Lower Snake rivers up to the 120% TDG tailwater and 115% TDG in the forebays of downstream projects as stipulated in the NOAA Fisheries 2004 Biological Opinion. The states of Oregon and Washington have provided TDG waivers for generating TDG at the levels specified in the BiOp during fish passage season. When systemwide TDG exceeds 120% TDG, then try to control systemwide TDG to 125%, then to 130%, and so on by spilling up to the spill caps indicated for those TDG levels at lower Columbia, Snake, mid-Columbia, HGH, and Willamette projects in the specified order. The listing order of the projects on the Spill Priority List depends upon specific river conditions, locations of juvenile and adult salmonids, specific configurations of the projects, and any special operational conditions (e.g. research studies, maintenance outages, etc.). The listing order and the specific spill quantities to achieve the various TDG levels will be updated as necessary to account for changing conditions in the rivers.

Table A-1.

Initial Spill Priority List for 2006

Project	Spill Cap to Generate Specific Percentage of Total Dissolved Gas (TDG)					
	110%	115%	120%	125%	130%	135%
LWG	20	30	42	90	125	200
LGS	20	25	32	80	110	250
LMN	10	15	40	55	110	250
BON	50	65	100	150	250	270
JDA	20	60	95	240	300	600
TDA	20	60	91	250	260	600
WAN	10	15	20	50	100	--
WEL	10	15	25	45	130 (1)	--
RRH	05	10	20	30	150 (1)	--
RIS	05	10	20	30	150 (1)	--
PRD	20	30	40	40	40	--
MCN	40	80	155	230	290	450
IHR	30	45	105	125	135	240
CHJ	05	10	15	33	45	--
GCL	20	25	30	75	--	--

(1) Limit daytime spill to 100 kcfs.