Water Quality Plan
for Total Dissolved Gas and Water Temperature in the Mainstem Columbia and Snake Rivers

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I. INTRODUCTION

The Water Quality Plan (WQP) was first introduced in the National Marine Fisheries Service's 2000 Biological Opinion concerning the operation of the Federal Columbia River Power System (2000 BiOp). In Appendix B of the 2000 BiOp, EPA, NOAA Fisheries, USFWS, and the Federal Action Agencies—the U.S. Army Corps of Engineers (Corps), Bonneville Power Administration (BPA), and Bureau of Reclamation (Reclamation)—committed to develop and implement a water quality plan to support Total Dissolved Gas (TDG) and temperature improvements in the Columbia River Basin. It was recognized in the 2000 BiOp that integration of the dissolved gas and water temperature actions of the Reasonable and Prudent Alternatives (RPA) and Appendix B would promote attainment of water quality standards as well as the recovery of endangered stocks. The 2000 BiOp also established a conservation recommendation for the development of a Water Quality Plan as a conceptual strategy for the mainstem temperature TMDL implementation plan for the Clearwater, Snake and Columbia rivers that are directly impacted by federal dams.

The first WQP, produced in April 2003, was developed in coordination with water quality regulatory agencies, other State and Federal agencies, Tribes and private entities. Implementation of the WQP for the Columbia River Basin has been ongoing, with updates in November 2004 and again in November 2006. The WQP focuses on implementable water quality measures to improve water quality conditions; primarily TDG and temperature. The geographic scope includes the Columbia River from Lake Roosevelt at the Canadian border, the Clearwater River from Dworshak Dam downstream to the lower Snake River, and from Brownlee Dam on the Snake River, to below Bonneville Dam on the lower Columbia. This plan also briefly addresses issues above the international border with Canada for consideration under the Clean Water Act. This coordination has led to Canadian efforts to reduce TDG levels in the Columbia River coming into U.S. waters at Lake Roosevelt.

This document sets forth the Corps' plan to improve water quality in the mainstem Columbia and Snake rivers with respect to: (1) actions in the 2008 NMFS Biological Opinion that pertain to improving water quality for ESA listed salmon and steelhead; (2) applicable TMDLs (currently there are three TMDLs for TDG in the lower-Columbia River, lower Snake River, and middle Columbia River, which are in effect until 2020); as well as, (3) other actions to move toward attainment of EPA-promulgated or approved State and Tribal water quality standards in the Columbia and Snake rivers.

The 2008 BiOp provides for continuing "to update the *Water Quality Plan for Total Dissolved Gas and Water Temperature in the Mainstem Columbia and Snake Rivers* and to implement water quality measures to enhance ESA-listed juvenile and adult fish survival and mainstem spawning and rearing habitat." The 2008 BiOp recommends that the Water Quality Plan include the following measures to address TDG to meet ESA responsibilities:

- ❖ Real-time monitoring and reporting of TDG and temperatures measured at fixed monitoring sites,

- ❖ Continued development of fish passage strategies with less production of TDG (e.g. removable, top, and adjustable spillway weirs) and update the System TDG (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,
- ❖ Investigate alternatives to reduce total mass loading of TDG at Bonneville Dam while maintaining juvenile survival performance, and
- ❖ Continued operation of lower Snake River projects at MOP.

EPA, NOAA Fisheries, USFWS, and the Action Agencies intend to integrate their fish and wildlife and water quality efforts to support the objectives of the ESA, CWA, and other statutes such as the Northwest Electric Power Planning and Conservation Act. Over the long term, with a focus on water quality, Plan implementation anticipates that EPA, NOAA Fisheries, and the Federal Action Agencies will properly integrate implementation of the Plan with ongoing TMDL development activities on the mainstem and in the sub-basins.

This Plan is consistent with the current Columbia and Snake River mainstem TDG TMDL actions. This plan has been coordinated with multiple agencies, which are identified in Appendix F. The Corps and Reclamation recommend continuing coordination between EPA, NOAA Fisheries, USFWS, and the northwest States and Tribes to resolve WQS attainability issues as they relate to Federal dams and operations to provide for authorized project purposes, while meeting CWA and ESA responsibilities. Procedures under the CWA to conduct a Use Attainability Analysis (UAA), develop site specific criteria, develop or modify compliance schedules, and other tools warrant discussion and exploration as means to meet the multiple objectives.

A. Regional Collaboration

The Water Quality Plan is a collaborative effort that ties into and coordinates with other past and current water quality efforts in the Region. In order to monitor, research, develop and improve the plan, several water quality teams or workgroups, including interagency and international teams, have formed to address water quality issues specific to the Columbia River Basin. Specific groups include the Regional Forum Water Quality Team, Mainstem Water Quality Plan Workgroup, Water Quality Workgroup, Transboundary Gas Group, and the Adaptive Management Team.

1. Regional Forum Water Quality Team

An interagency TDG team met periodically to discuss dissolved gas issues, physical and biological monitoring protocols, project operations, and spill management as ESA listings of salmon species occurred in the early 1990s and BiOps were issued by NOAA Fisheries. As temperature became an issue for regional discussion, the team’s scope expanded to include water temperature. As part of this change, the team changed its name to the Water Quality Team

(WQT). The WQT was incorporated into the 1995 BiOp regional implementation forum, along with the Technical Management Team and the System Configuration Team, to coordinate the implementation of water quality measures in the BiOp. The WQT continued to meet until 2007 when the Adaptive Management Team formed.

The Regional Implementation Oversight Group (RIOG), a policy level interagency committee recently formed as part of the 2008 BiOp implementation, includes a water quality coordination group in its draft framework. Therefore a regional water quality discussion group will continue to exist for 2008 BiOp implementation.

2. Mainstem Water Quality Plan Workgroup

The Mainstem Water Quality Plan Workgroup (Workgroup) was formed in 2001 and met periodically to coordinate the completion of the April 2003 Plan. The Workgroup produced a detailed outline of a comprehensive Mainstem Water Quality Plan and agreed to the following purpose statement to guide the group's efforts:

- The Mainstem Water Quality Plan Workgroup will work to identify short-term actions for funding and implementation while working towards a long-term water quality plan for the mainstem that coordinates the FCRPS, Northwest Power Planning Council sub-basin plans and the Clean Water Act to benefit fish.

In pursuit of this purpose the Workgroup also discussed and agreed to the following goals:

- Provide an implementation plan for water quality actions as called for in Appendix B of the NOAA Fisheries 2000 FCRPS Biological Opinion.
- Serve as an implementation framework for the Columbia and Snake rivers mainstem TMDLs.
- Serve as the implementation framework for TDG waivers for the Corps of Engineers implementation of the Biological Opinion spill program.
- Full engagement of the Columbia River action agencies.
- Commitment to ongoing Federal Executives dialogue.
- Commitment to use unified and best available science, and
- Commitment to fund the plan development.

Since the completion of the April 2003 Mainstem Water Quality Plan, the Workgroup has been asked to comment on updates to the Plan that were completed in December 2003, December 2004, and November 2006, and the current update.

3. Water Quality Workgroup/Water Quality Team Coordination

The Mainstem Water Quality Plan Workgroup is tasked with addressing specific technical issues as they arise in support of regional water quality planning and policies. Examples of technical issues could include but would not be limited to TDG or water temperature improvement topics, research needs or designs, monitoring strategies, or TMDL compliance concerns. In these instances the RIOG water quality coordination group, operating in support of the Biological Opinion implementation may be called on for assistance. The Workgroup could also communicate with the other technical teams serving the NOAA Fisheries and the regional policy level group. These teams include the System Configuration Team and the Technical Management Team regarding issues of FCRPS modification and operation, respectively.

4. Transboundary Gas Group

The Transboundary Gas Group (TGG) was formed in April 1998 during an international conference attended by scientists, planners, and policy-makers from federal, state and provincial agencies, tribes and first nations, private industry, utility owners/operators, and public interest groups from Canada and the United States. The TGG was formed to help coordinate dissolved gas planning activities between Canada, the United States, tribes, first nations, and other organizations. The overall, long-term goal of the TGG is to:

> *"Reduce systemwide total dissolved gas to levels safe for all aquatic life in the most cost-effective manner possible"*

Initially, a steering committee was developed to help guide the efforts of the group and to monitor its fulfillment of the group's goals. Four technically focused workgroups were also formed to assist in the development of a framework plan. The four groups were:

- Biological Effects and Research
- Monitoring and Information Sharing
- Modeling (Computer Simulations)
- Operational and Structural Gas Abatement

For many years, the TGG met twice each year, usually in the early spring and again in the fall. Since 2007, however, the TGG has reduced the frequency of meetings to once per year. The latest developments in dissolved gas monitoring, abatement methods, modeling, and biological effects are discussed at the meetings. The group has also offered opinions and guidance regarding dissolved gas questions that have arisen in the Pacific Northwest.

To date the TGG has developed a "Framework Plan for Coordinating Activities of the Columbia River Transboundary Gas Group" and offered Canadian energy entities, specifically Columbia Power Corporation and Tech-Cominco, letters endorsing structural and operational gas abatement initiatives. Through contractual support by the British Columbia Ministry of Environment, Lands, and Parks the TGG also produced a paper addressing the international treaties affecting potential water quality actions and remediation, Treaty Implications of Dissolved Gas Management in the Columbia River Basin

5. Adaptive Management Team

The TDG TMDLs for the Columbia and lower Snake rivers call for an Adaptive Management Team (AMT) to guide implementation of the TMDL and the Water Quality Implementation Plans that are developed as part of the TMDL process. At an Oregon Environmental Quality Commission (EQC) public hearing in Portland in June 2007, the EQC instructed the Oregon DEQ and advised the Washington DOE to immediately convene the AMT to discuss the need for the 115% forebay TDG limit that is in place as part of the state TDG waivers/criteria adjustments. The Oregon DEQ was given authority to change the forebay TDG limit, if appropriate, based on information provided and discussed with the AMT. The AMT, co-chaired by Washington DOE and Oregon DEQ, held its first meeting in November 2007. AMT membership includes the following agencies and organizations:

- State of Washington (Ecology co-chair)
- State of Oregon (ODEQ co-chair)
- NOAA Fisheries
- USACE
- Save our Wild Salmon
- Colville Tribal Representative
- CRITFC Tribal Representative
- PUD Representative
- EPA
- NW River Partners
- USFWS

In addition to AMT members, the Fish Passage Center, BPA, ODFW, and consultants have provided technical information and comments. The AMT role and functions are described in the states' report, "Adaptive Management Structure for the Columbia and Snake River Total Dissolved Gas Total Maximum Daily Load", dated September 2007. Their report is located at: http://www.ecy.wa.gov/programs/wq/tmdl/ColumbiaRvr/AMTConceptPaper.pdf

Since November 2007 AMT meetings have been held about once a month, with numerous technical presentations, reports, and comments on the information provided. The states are applying this information to make a determination on the need for the 115% forebay TDG limit and, if needed, modify their TDG Water Quality Standards using each state's process for rule changes including public review and comment.

After the forebay question is addressed, the states have indicated that they wish to consider the location of tailrace TDG monitors. The AMT also may guide the TMDL transition from short term to longer term implementation starting in 2010.

The Corps will continue to participate in these discussions, coordinate with the States of Oregon and Washington on voluntary spill for fish passage, and provide technical information to inform the States' process. TDG gauge locations and spill operations may be modified in the future through the implementation planning process and adaptive management. The Corps' decisions on the spill program will consider water quality effects along with the results of physical spill studies, biological evaluations, and the relationship to achieving BiOp performance standards for FCRPS projects. AMT products, including meeting minutes, documents, and the states' synthesis report, are available on the AMT web site, located at: http://www.ecy.wa.gov/programs/wq/tmdl/ColumbiaRvr/ColumbiaTDG.html

B. Goals

The goal of the Water Quality Plan is to outline the physical and operational changes that have been identified to improve the overall water quality in the Clearwater, Snake and Columbia rivers that are directly impacted by federal dams, and to conserve threatened and endangered species within these waters. Other objectives of the plan include:

- To assist in our understanding of system wide loading capacity and loading allocation by assessing the existing effects at Federal and non-Federal dams and tributaries.

- To provide an organized, coordinated approach to improving water quality.

- To provide a framework for identifying, evaluating, and implementing technologically and economically feasible actions for dam operators to use in managing water temperature and TDG levels.

- To provide a record of the actions that are and are not feasible for structural and operational changes aimed at improving water quality conditions with the objectives of moving toward attainment of applicable water quality standards.

- To bring basin wide information on TDG and water temperature into the decision processes, and to provide technical assessment of a project's relative value in terms of water quality.

- To integrate TDG and water temperature work into one process for both Federal and non-Federal dams on the mainstem Columbia River and Snake River system.

II. BACKGROUND

TDG supersaturation occurs in many rivers throughout the world. It has been noted to be a particular problem in the Columbia River Basin. The Columbia River is listed as an impaired water body on the States' 303(d) list for both TDG and temperature. Excess TDG can be a serious threat to the health of aquatic life, producing a class of physiological problems known as Gas Bubble Trauma (GBT). This condition causes the growth of internal or external gas bubbles, which can be fatal to fish. TDG saturation levels are also influenced by water temperature, which by itself can influence the health of fish and other aquatic organisms.

Water temperature conditions have a complex array of effects on salmonids. Water temperatures affect the rate of embryonic development, post-emergence growth rates, and smolt survival. Water temperature also indirectly affects salmon survival by its effects on foraging rates of predatory fish and the rates of infertility and mortality rates of several diseases in adult salmon. In addition, an emerging issue is potential water temperature effects on juvenile outmigration timing (NMFS 2000). A hypothesis is that the Snake River juvenile fall Chinook outmigration timing may be delayed by cooler-than-historical water temperatures during incubation and early rearing life stages due to the modified releases from Dworshak Dam.

Both TDG and water temperature are closely linked to water management operations. Water released through the dam spillways, through the powerhouses and other facilities, as well as forebay and tailwater water surface elevations can affect water quality. When water is spilled at a dam, bubbles of air are entrained. As the water plunges into the deep pool (stilling basin) at the base of the dam, the air bubbles carried to depth are subjected to hydrostatic pressure that forces them to dissolve into the water. The air bubbles consist mainly of oxygen and nitrogen, with traces of argon and carbon dioxide, each of which exerts pressure. When the sum of the partial pressures of the gases in the water exceeds their partial pressures in the atmosphere, the condition is called dissolved gas supersaturation. The amount of TDG created increases with water temperature, spill volumes, and spillway plunge depth.

Gas can also be entrained into water that passes through dam turbines or through low-level ports in the dam. Air can become entrained in vortices near the ports or turbine intakes and can be forced into solution due to the very high level of hydrostatic pressure that exists near the ports and turbines but typically, more dissolved gas is created when water is spilled than when it is routed through turbines. Dissolved gas can persist in the river for significant distances downstream; however, each dam has its own unique and strongly localized gassing effect. For instance, Kaplan turbines on Snake and Columbia River dams generally do not entrain air and do not generate TDG, rather they simply pass downstream the TDG levels which are present in the forebay waters. Dworshak Dam, however, has Francis turbine units and air is introduced to those units (aspiration) to control cavitation that can physically damage the machines and adjacent supporting structures. TDG is generated when the units are being aspirated, normally during low turbine discharges.

Voluntary spill at dams occurs primarily to assist juvenile salmon migration at mainstem run-of-river projects. The operation is done to decrease residence time of juvenile salmon in the forebay of the dam and to provide a passage route that typically has a higher survival rate than most other routes of passage at the dam. Involuntary spill occurs occasionally at a dam either due to the physical limitations of the system (the flow exceeds the hydraulic capacity of the powerplant), or because the flow exceeds the available market for the power that can be generated by the plant (overgeneration spill). Project spill at storage reservoirs to maintain needed flood control space is also considered involuntary spill.

Due to the impacts of GBT to fish health and the potential of Federal dam operations to contribute to TDG in the Columbia River Basin, TDG is a primary water quality parameter monitored by the Corps. Since TDG saturation levels are also influenced by water temperature, and temperature by itself can influence the health of fish and other aquatic organisms, water temperature is also monitored in order to determine TDG influences and take actions to improve aquatic species health.

A. Corps of Engineers Water Quality Policy

The general policies of the Corps related to water quality are summarized in the **Corps Digest of Water Resources Policies and Authorities**, Engineering Pamphlet 1165-2-1, dated July 31, 1999(USACE 1999). This Engineering Pamphlet can be found at: http://140.194.76.129/publications/eng-pamphlets/ep1165-2-1/toc.htm

The Corps policy is to meet water quality standards to the extent practicable regarding nationwide operation of water resources projects. "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," (Section 18-3.b, page 18-5). The data from the Corps Dissolved Gas Monitoring Program before 1984 was used to voluntarily monitor for compliance with water quality standards. In 1984, the Corps Dissolved Gas Monitoring Program was enhanced to serve the multiple purposes stated in the Corps policies and authorities.

With the ESA listing of certain Snake River salmonids in 1991, the Corps implemented a variety of operational and structural measures to improve the survival of listed stocks. Actions included providing summer releases of available water for flow augmentation for migrating juvenile salmon where possible, and to a level of 120% TDG where State rule modifications, or waivers had been provided. This spill level has become an annual operation for the benefit of ESA listed juvenile fish.

The Corps addressed TDG and water temperature in ESA consultations with NMFS since the early 1900's. The Corps adopted the recommendations contained in the NMFS BiOps. The 2008 BiOp has set levels of spill for fish passage which will be implemented starting in 2009 using an adaptive management framework. Therefore spill levels have flexibility to change over the 10-year implementation period of the BiOp, incorporating the best available information from research to best meet BiOp performance standards and improve fish conditions.

B. Water Quality Standards

1. TDG Standards

a. Idaho TDG Standards

The State of Idaho was approached in 2001 concerning a waiver to water quality standards. The State, in conjunction with the tribes, provided a set of conditions that must be met as part of the waiver process. Due to the conditions provided by the State and tribes, the forecasted drought conditions and the foreseen use of Dworshak water releases, there was no further pursuit of a water quality waiver by the Corps after the 2001 water year. The State WQS of 110% for TDG is generally met. Idaho's water quality criteria is set forth in IDAP 58.01.02.

b. Oregon TDG Standards

The State of Oregon TDG water quality standards are contained in OAR 340-041-0031. The standard states that waters will be free from dissolved gases, for example carbon dioxide, hydrogen sulfide, and other gases, in sufficient quantities to cause objectionable odors or to be deleterious to fish or other aquatic life, navigation, recreation, or other reasonable water uses. For TDG levels, the standard states that, except when stream flow exceeds the ten-year, seven-day average flood, the concentration of TDG relative to atmospheric pressure at the point of sample collection may not exceed 110 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.

Oregon's rules allow for modifications to the standard for the purpose of allowing increased spill for salmonid migration on the mainstem Columbia River (OAR 340-041-0104). This is done by action of the Oregon Environmental Quality Commission. In order to grant a rule modification or waiver, the Commission must find the following:

(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 took appropriate actions for receiving a TDG rule modification from the State of Oregon for the 2002-2009 spill seasons. The first Federal request for a TDG rule modification was submitted to the Oregon Department of Environmental Quality (ODEQ) in 1996. The first request from the Corps was in 2002, and included a report of the 2001 TDG monitoring program accompanied by a request for a waiver for the 2002 spill season. The Oregon Environmental Quality Commission met on March 8, 2002 and approved a waiver for the upcoming spill season. Based on this approval, the ODEQ issued a modification to the TDG standard, subject to specific conditions, as signed by Stephanie Hallock on March 8, 2001, and was to be in effect from midnight on April 1, 2002 to midnight August 31, 2002. The Commission approved a modification to the TDG standard for spill on the Columbia River of a daily (12 highest hours) average of 115% as measured in the forebay of McNary, John Day, The Dalles, and Bonneville dams, and at the Camas/Washougal monitoring stations. They approved a cap on TDG for the Columbia River during the spill program of 120% measured at the McNary, John Day, The Dalles, and Bonneville dams' tailwater monitoring stations, based on the average of the 12 highest hourly measurements per calendar day. The Commission also approved a cap on TDG for the Columbia River during the spill program of 125%, based on the highest two hours per calendar day. The Commission also required that if 15% of the juvenile fish examined showed signs of gas bubble disease in their non-paired fins, where more than 25% of the surface area of the fin was occluded by gas bubbles, the waiver would be terminated.

The following conditions were incorporated into the Commission's waiver. The Corps was to provide written notice within 24 hours to the (ODEQ) on any exceedances of the conditions in the waiver as it relates to voluntary spill. The Corps was to provide a written report of the 2002 spill program by December 31, 2002 and supply information on the levels of TDG, fish monitoring, and incidence and severity of GBT. Additionally, any proposal for a modification to the TDG standard in 2003 was to be received by the (ODEQ) no later than December 31, 2002.

On December 23rd, 2002, the Corps provided information for a multi-year TDG waiver to the ODEQ. The Oregon Environmental Quality Commission met on March 11th, 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 from April 1 through August 31 of each year through the 2007 spill season.

On November 30, 2006, the Corps provided 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. The waiver issued was similar to the previous waivers with the exception that the 115% criterion as measured at the Camas-Washougal fixed monitoring station was removed and that the year-end report include a description and results of any biological or physical studies of spillway structures and prototype fish passage devices to test spill at operational levels. It also included a provision for Adaptive Management which outlined a process for the evaluation of appropriate points of compliance for the 2002 Lower Columbia River Total Dissolved Gas Total Maximum Daily Load (TMDL).

c. Washington TDG Standards

In its 1997 water quality standards, the State of Washington modified its rule on TDG to allow for adjusted TDG criteria when spilling water over dams to aid fish passage. The 1997 rule (WAC 173-201A-060(4)(a)), stated that, subject to approval of a gas abatement plan, and submission of a fisheries management plan, and plans for physical and biological monitoring, TDG levels in the river may be elevated to allow increased fish passage without causing more harm to fish populations than caused by turbine fish passage. The exemption required that, when spilling water at dams is necessary to aid fish passage, TDG must not exceed an average of one hundred fifteen percent as measured at Camas/Washougal below Bonneville dam or as measured in the forebays of the next downstream dams. TDG must also not exceed an average of one hundred twenty percent, as measured in the tailraces of each dam. These averages are based on the twelve highest hourly readings in any one day of TDG. In addition, there is a maximum TDG one hour average of one hundred twenty-five percent, relative to atmospheric pressure, during spillage for fish passage.

In December 2002, the Corps provided documents to the WDOE for a TDG criteria adjustment. In a letter to the Corps dated March 28, 2003, the WDOE approved the gas abatement plan for all activities related to fish passage for a period of one year.

In July, 2003 the State of Washington revised its water quality standards rule, 173-201A and made some significant changes related to compliance of the water quality standards for hydropower dams. One significant change to TDG was removing the “temporary” nature of the special condition for fish spill on the Columbia and Snake Rivers (see WAC 173-201A-200(1)(f)(ii)). The other was the addition of new language to address compliance schedules for dams (see WAC 173-201A-510(5)). These new water quality standards were officially approved by EPA 12 February 2008.

In December 2003, the Corps again provided a set of documents to the WDOE which included 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 for only one year, in order to coincide with Oregon’s waiver time limit.

On January 14, 2005, the Corps provided documents in response to the State of Washington’s request for a TDG gas abatement plan. In this package, the gas abatement plan was updated as of December 2004. Based on this submittal and additional coordination with the Corps and Oregon DEQ, the WDOE approved the rule adjustment for a period of three years (through February 2008). This criteria adjustment continued to call for 115% forebay and 120% tailrace TDG limits but did not call for a gauge at Camas/Washougal as previous WDOE criteria adjustments had done.

In addition to the TDG requirements described above, as part of the approval of the Water Quality Plan and making the criteria adjustment for three years, the Corps was to continue to investigate and pursue TDG reduction and monitoring improvement as new information becomes available, continue to investigate biological effects of TDG, make reasonable attempts to reduce gas entrainment during all flows during the spill season, plan maintenance schedules and activities as much as possible to minimize TDG production, notify WDOE within 48 hours of initiation of spring, summer, and other spills for fish, and provide the WDOE with an annual written report detailing TDG issues and characteristics for each year of spill season.

On November 30, 2006, the Corps provided updated documents to the State of Washington concerning a TDG criteria adjustment. In this package, the gas abatement plan was updated as of November 2006. Based on this submittal and additional coordination with the Corps and Oregon DEQ, the WDOE provided a letter to the Corps, dated February 8, 2008, which approved the Corps' Water Quality Plan and adopted a criteria adjustment for a period of two years (March 2008 through February 2010). In addition to the reporting requirements that were requested in previous rule adjustments, this version requested that the Corps investigate and pursue TDG reduction improvements for all projects on the lower Columbia and Snake rivers and Chief Joseph Dam and to produce a draft report by October 31, 2008 and a final report by December 31, 2008. This ongoing investigation will evaluate each dam's ability to attain WQS for TDG.

2. Modifications to TDG Standards for Juvenile Fish Passage

In order to be consistent with ESA recommendations to implement "voluntary" spill to assist juvenile salmonids passage past mainstream dams, the Corps has been coordinating with the appropriate State water quality agencies, which have provided TDG waivers and criteria adjustments. These waivers adjust the TDG criteria when "voluntary" spill was needed. From 1996 through 2007, the states had provided rule modifications (Oregon) and criteria adjustments (Washington), and voluntary spill for fish passage has been managed as needed so that TDG levels in the tailraces of projects do not exceed 120%, and do not exceed 115% in the forebays of any lower Snake River or lower Columbia River dam or at the Camas/Washougal station, as measured by the 12 highest hourly measurements in any calendar day. The rule modification and criteria adjustments provided by the States of Oregon and Washington for the 2008 and 2009 spill seasons have not specified the use of the Camas/Washougal FMS for TDG management.

The Corps provides the WQP to the states of Oregon and Washington in support of their processes to modify or adjust TDG criteria.

3. Water Temperature Standards

The Columbia River Basin encompasses parts of British Columbia, Idaho, Oregon, Washington, Montana, Nevada, Utah and Wyoming, with each state adopting its own water quality standards. In addition, various Columbia basin tribes have water quality standards. Of primary interest of this Water Quality Plan are the States of Idaho, Oregon and Washington and regional tribes. Although some of these entities have water quality standards, EPA has approved only the plans the states of Idaho, Oregon and Washington and promulgated the standards of the Colville Tribe.

a. Idaho Temperature Standards

The Idaho Water Quality Standard for water temperature is segregated by beneficial use of the water. The uses of interest in this document are the following two subcategories of aquatic life:

> <u>i. Cold water (COLD):</u> water quality appropriate for the protection and maintenance of a viable aquatic life community for cold water species.

Waters designated for cold water aquatic life are not to vary from the following characteristics due to human activities: Water temperatures of 22 degrees C (71.7 degrees, F) or less, with a maximum average daily average of no greater than 19 degrees C (66.2 degrees, F).

> <u>ii. Salmonid spawning (SS):</u> waters that provide or could provide a habitat for active self-propagating populations of salmonid fishes.

Waters designated for salmonid spawning are to exhibit the following characteristics during the spawning period and incubation for the particular species inhabiting those waters: Water temperatures of 13 degrees C (55.4 degrees, F) or less, with a maximum daily average of no greater than 9 degrees C (48.2 degrees, F).

Note that SS appears in Idaho's rules as a subsection under cold-water aquatic life. Thus the qualification for human caused deviation from the criteria also applies. These rules also state that when natural background conditions exceed any applicable criteria, pollutant levels shall not exceed the natural background condition, except that point sources may increase temperature levels up to 0.3°C above natural background. Idaho's natural background provisions were extended to cover temperature in 2000, and modified to include the point source de-minimus increase in 2002. These changes have been reviewed by EPA, and were approved as needed in July 2004.

b. Oregon Temperature Standards

The State of Oregon water quality standards for temperature are contained in OAR 340-041-0028. The standards include background and policy for EQC consideration, along with specific biologically based standards for various water bodies. The following excerpt from the standard is shown below.

> (1) Background. Water temperatures affect the biological cycles of aquatic species and are a critical factor in maintaining and restoring healthy salmonid populations throughout the State. Water temperatures are influenced by solar radiation, stream shade, ambient air temperatures, channel morphology, groundwater inflows, and stream velocity, volume, and flow. Surface water

temperatures may also be warmed by anthropogenic activities such as discharging heated water, changing stream width or depth, reducing stream shading, and water withdrawals.

(2) Policy. It is the policy of the Commission to protect aquatic ecosystems from adverse warming and cooling caused by anthropogenic activities. The Commission intends to minimize the risk to cold-water aquatic ecosystems from anthropogenic warming, to encourage the restoration and protection of critical aquatic habitat, and to control extremes in temperature fluctuations due to anthropogenic activities. The Commission recognizes that some of the State's waters will, in their natural condition, not provide optimal thermal conditions at all places and at all times that salmonid use occurs. Therefore, it is especially important to minimize additional warming due to anthropogenic sources. In addition, the Commission acknowledges that control technologies, best management practices and other measures to reduce anthropogenic warming are evolving and that the implementation to meet these criteria will be an iterative process. Finally, the Commission notes that it will reconsider beneficial use designations in the event that man-made obstructions or barriers to anadromous fish passage are removed and may justify a change to the beneficial use for that water body.

(3) Purpose. The purpose of the temperature criteria in this rule is to protect designated temperature-sensitive, beneficial uses, including specific salmonid life cycle stages in waters of the State.

(4) Biologically Based Numeric Criteria. Unless superseded by the natural conditions criteria described in section (8) of this rule, or by subsequently adopted site-specific criteria approved by EPA, the temperature criteria for State waters supporting salmonid fishes are as follows:

(d) The seven-day-average maximum temperature of a stream identified as having a migration corridor use on subbasin maps and tables OAR 340-041-0101 to 340-041-0340: Tables 101B, and 121B, and Figures 151A, 170A, and 340A, may not exceed 20.0 degrees Celsius (68.0 degrees Fahrenheit). In addition, these water bodies must have coldwater refugia that's sufficiently distributed so as to allow salmon and steelhead migration without significant adverse effects from higher water temperatures elsewhere in the water body. Finally, the seasonal thermal pattern in Columbia and Snake Rivers must reflect the natural seasonal thermal pattern;

(7) Oceans and Bays. Except for the Columbia River above river mile 7, ocean and bay waters may not be warmed by more than 0.3 degrees Celsius (0.5 degrees Fahrenheit) above the ambient condition unless a greater increase would not reasonably be expected to adversely affect fish or other aquatic life.

(8) Natural Conditions Criteria. Where the department determines that the natural thermal potential of all or a portion of a water body exceeds the biologically-based criteria in section (4) of this rule, the natural thermal potential temperatures supersede the biologically-based criteria, and are deemed to be the applicable temperature criteria for that water body.

(See, OAR 340-041-0028)

c. Washington Temperature Standards

The standards below are the November 2006 Washington WQS for water temperature as applied to the mainstem Columbia and Snake Rivers. These standards were updated from the 1997 standards and became fully effective when the US EPA formally approved the new State standards in February 2008. Surface water quality standards for the State of Washington are contained in WAC 173-201A.

The Washington water quality standards, the water quality standards are designated based on the aquatic life use categories. These categories are listed in the WAC 173-201A-200(1)(c) and shown in Table 1.

Table 1: Aquatic Life Temperature Criteria in Fresh Water

Category	Highest 7-DADMax
Char Spawning	9°C (48.2°F)
Char Spawning and Rearing	12°C (53.6°F)
Salmon and Trout Spawning	13°C (55.4°F)
Core Summer Salmonid Habitat	16°C (60.8°F)
Salmonid Spawning, Rearing, and Migration	17.5°C (63.5°F)
Salmonid Rearing and Migration Only	17.5°C (63.5°F)
Non-anadromous Interior Redband Trout	18°C (64.4°F)
Indigenous Warm Water Species	20°C (68.0°F)

When a water body's temperature is warmer than the criteria in Table 1, (or within 0.3°C (0.5°F) of the criteria) and that condition is due to natural conditions, then human actions considered cumulatively may not cause the 7-DMax temperature of that water body to increase more than 0.3°C (0.5°F).

Incremental temperature increases resulting from point source activities shall not, at any time, exceed $t=28/(T+7)$ (freshwater) or $t=12/(T-2)$ (marine water). Incremental temperature increases resulting from non-point source activities shall not exceed 2.8ºC. For purposes hereof, "t" represents the maximum permissible temperature increase measured at a mixing zone boundary; and the "T" represents the background temperature as measured at the point or points unaffected by the discharge and representative of the highest ambient water temperature in the vicinity of the discharge."

The Columbia River from the mouth to the Washington-Oregon border (river mile 309.3) is designated as Spawning, Rearing, and Migration with a special condition. The temperature shall not exceed 20.0ºC (68.0ºF) due to human activities. When natural conditions exceed 20.0ºC (68.0ºF), no temperature increase will be allowed which will raise the receiving water temperature by greater than 0.3ºC (0.5ºF); nor shall such temperature increases, at any time, exceed 0.3ºC (0.5ºF) due to any single source or 1.1ºC (1.9ºF) due to all such activities combined.

The Columbia River from the Washington-Oregon border (river mile 309.3) to Grand Coulee Dam (river mile 596.6) is also designated as Spawning, Rearing, and Migration and has a special condition from Washington-Oregon border (river mile 309.3) to Priest Rapids Dam (river mile 397.1). The temperature shall not exceed 20.0ºC (68.0ºF) due to human activities. When natural conditions exceed 20.0ºC (68.0ºF), no temperature increase will be allowed which will raise the receiving water temperature by greater than 0.3 ºC (0.5ºF); nor shall such temperature increases, at any time, exceed t=34/(T+9)[between 1.13ºF and 0.9ºF].

The Columbia River from Grand Coulee Dam (river mile 596.6 to the Canadian border (river mile 745.0) is designated as Core Summer Salmonid Habitat and has no special temperature condition.

The Snake River from the mouth (confluence with the Columbia River) to the Washington-Idaho-Oregon border (river mile 176.1) is designated Spawning, Rearing, and Migration with a special condition.

(a) Below the Clearwater River (river mile 139.3): The temperature shall not exceed 20.0°C (68.0°F) due to human activities. When natural conditions exceed 20.0°C (68.0°F), no temperature increase will be allowed which will raise the receiving water temperature by greater than 0.3°C (0.54°F); nor shall such temperature increases, at any time, exceed t=34/(T+9).

(b) Above the Clearwater River (river mile 139.3): The temperature shall not exceed 20.0°C (68.0°F) due to human activities. When natural conditions exceed 20.0°C (68.0°F), no temperature increases will be allowed which will raise the receiving water temperature by greater than 0.3°C (0.54°F); nor shall such temperature increases, at any time, exceed 0.3°C (0.54°F) due to any single source or 1.1°C (1.9°F) due to all such activities combined.

d. Colville Tribal Temperature Standards

The WQS for the Confederated Tribes of the Colville Reservation were promulgated by EPA at 40 CFR 131.135. These standards apply to the Columbia River from the northern boundary of the reservation downstream to Wells Dam. The Columbia River is designated as "Class I (Extraordinary)" from the Northern Border of the Reservation to Chief Joseph Dam and "Class II (Excellent)" from Chief Joseph Dam to Wells Dam. The designated uses most sensitive to temperature are "Fish and shellfish: Salmonid migration, rearing, spawning and harvesting: other fish migration, rearing, spawning and harvesting."

The use designations and corresponding temperature criteria for the Colville Tribe are as follows:

Class I (Extraordinary)—Fish and shellfish: Salmonid migration, rearing, spawning, and harvesting: Temperature shall not exceed 16°C due to human activities. Temperature increases shall not, at any time, exceed t = 23/(T + 5). When natural conditions exceed 16°C, no temperature increase will be allowed that will raise the receiving water by greater than 0.3°C. For purposes hereof, "t" represents the permissive temperature change across the dilution zone; and "T" represents the highest existing temperature in this water classification outside of any dilution zone. Temperature increase resulting from nonpoint source activities shall not exceed 2.8°C and the maximum water temperature shall not exceed 16.3°C.

Class II (Excellent)—Fish and shellfish: Salmonid migration, rearing, spawning, and harvesting: Temperature shall not exceed 18°C due to human activities. Temperature increases shall not, at any time, exceed t = 28/(T + 7). When natural conditions exceed 18°C, no temperature increase will be allowed that will raise the receiving water by greater than 0.3°C. For purposes hereof, "t" represents the permissive temperature change across the dilution zone; and "T" represents the highest existing temperature in this water classification outside of any dilution zone. Temperature increase resulting from nonpoint source activities shall not exceed 2.8°C and the maximum water temperature shall not exceed 18.3°C.

Class III (Good)—Fish and shellfish: Salmonid migration, rearing, spawning, and harvesting: Temperature shall not exceed 21°C due to human activities. Temperature increases shall not, at any time, exceed t = 34/(T + 9). When natural conditions exceed 21°C, no temperature increase will be allowed that will raise the receiving water by greater than 0.3°C. For purposes hereof, "t" represents the permissive temperature change across the dilution zone; and "T" represents the highest existing temperature in this water classification outside of any dilution zone. Temperature increase resulting from nonpoint source activities shall not exceed 2.8°C and the maximum water temperature shall not exceed 21.3°C.

Class IV (Fair)—Salmonid migration. Temperature shall not exceed 22°C due to human activities; T increases shall not exceed t = 20/(t + 2). When natural conditions exceed 22°C no temperature increase will be allowed which will raise the receiving water temperature by greater than 0.3°C. For purposes hereof, "t" represents the permissive temperature change across the dilution zone; and "T" represents the highest existing temperature in this water classification outside of any dilution zone.

4. Snake and Columbia Water Temperatures – A Corps of Engineers Perspective

Based on review of the limited historical data, the Corps has concluded that water temperatures in the Snake and Columbia mainstem rivers regularly exceeded 20°C during summer months prior to impoundment. The Corps also believes that temperatures are generally warmer today than they were historically. As such, to characterize hydropower development as the singular reason current temperatures are warmer than historic is inaccuarate. The Corps concludes that water temperatures are currently warmer than historic conditions primarily based on the combined effects of:

- Construction and Operation of the Federal and Private Columbia/Snake Mainstem Dams
- Climate Changes
- Upstream Influences

A brief discussion of the Corps perspective is presented in Appendix E.

C. Total Maximum Daily Loads (TMDLs) and Implementation Plans

A TMDL is a CWA tool for meeting water quality standards for 303(d) designated waterbodies with water quality impairments. It is based on the relationship between pollution sources and in-stream water quality conditions, and is calculated to protect the most sensitive beneficial use. A TMDL establishes compliance locations, loading capacity, load allocations and implementation strategies. The implementation controls should provide the pollution reduction necessary for a water body to eventually meet water quality standards. TMDLs are typically developed by States or tribes and approved through the EPA. However, EPA may also develop a TMDL.

Spill events result in elevated TDG levels at each of the projects on the Columbia and Snake rivers within the States of Washington and Oregon, and these entire reaches are considered impaired for TDG. The states of Oregon and Washington have both listed multiple reaches of the lower Columbia River on their federal CWA 303(d) lists due to TDG levels exceeding state water quality standards.

Most of the Snake River from its confluence with the Salmon River at RM 188 to its confluence with the Columbia River has been included on the 303(d) list of impaired waters for temperature and TDG by Idaho, Oregon or Washington as appropriate. Oregon and Washington also included most of the Columbia River on their 303(d) lists for temperature. The Columbia River exceeds the WQS of the Colville Confederated Tribes and the Spokane Tribe of Indians. For more information on Tribal WQ standards see: http://yosemite.epa.gov/r10/water.nsf/6cb1a1df2c49e4968825688200712cb7/b3f932e58e2f3b9488256d16007d3bca!OpenDocument

As noted above, the WQS for both Oregon and Washington include the same TDG criterion: *110 percent of saturation not to be exceeded at any point of measurement*. In addition, Oregon's rule has a limit of 105% TDG in hatchery receiving waters and in water less than 2 feet in depth. These criteria do not apply to flows above the seven-day, ten-year frequency flow (7Q10) flood flow. In addition, special waiver/criterion adjustment to limits for TDG have been established as a temporary special condition in Washington rules, to allow higher criteria with specific averaging periods during periods of spill for fish passage. Oregon rules specify a process for establishing modified limits on an annual basis. Because the waiver/criterion adjustment limits are either temporary or annually renewed, this TMDL addresses only the 110 percent criterion. However, the implementation plan provides for TDG waiver limits through 2010.

Loading capacity for TDG has been defined in terms of excess pressure over barometric pressure. This parameter was chosen because it can be directly linked to the physical processes by which spills generate high TDG, and it has a simple mathematical relationship to TDG percent saturation. A loading capacity of 75 mm Hg has been assigned to the Columbia River in this TMDL area, based on meeting 110% saturation during critically low barometric pressure conditions.

Because of the unique nature of TDG, load allocations for spill as dams are not directly expressed in terms of mass loading. Like loading capacity, load allocations for each dam will be made in terms of excess pressure over barometric pressure defined site-specifically for each dam. A load allocation is also specified for the upstream boundary of the TMDL area. The wasteload allocation under the TMDL is zero, because no NPDES-permitted sources produce TDG.

In the long term, load allocations for spill at dams will be at the downstream end of the aerated zone below each spillway. Distances are specified for the compliance location at each dam. As a result, the load allocation for spill at each dam is monitored at a specified location, with allowance made for degassing in the tailrace below the spillway and above the monitoring location.

Load allocations are also tied to structural changes at each dam, and are intended as long-term targets. In the near term, the implementation plan incorporates operational management of spills, implementation of the "fast-track" DGAS structural modifications, Endangered Species Act actions, and TDG waiver criteria.

TMDL implementation plans, also called Water Quality Management Plans (WQMP), are developed to achieve the load allocations identified in the TDG TMDL. For Columbia/Snake Mainstem TDG TMDLs, implementation plan development is the responsibility of the States of Oregon and Washington in coordination with Columbia Basin Tribes and approved by EPA, and implementation is the responsibility of the Corps.

The TDG TMDL implementation strategy outlines a two-phased approach for reducing gas levels. The first phase is meant to identify the activities that are planned for completion in the short-term, roughly through 2010, that will help to reduce TDG levels as well as ensure the fish passage requirements as set out in the relevant BiOp. Phase II identifies action items that are planned for the longer term, to potentially take place in 2011-2020 if warranted. However the Corps believes that the combination of all of these items, while making substantial progress towards attainment of the goals, may not get TDG to the desired attainment levels in all flow years. As indicated in the Lower Columbia TMDL, pg. 69, and in the Lower Snake TMDL, pg. 73:

> *Clearly, if spilled water is the cause of elevated TDG levels but is required for fish passage, care needs to be taken not to implement gas abatement measures that may benefit water quality, while damaging the beneficial uses, such as juvenile migration, that the federal Clean Water Act was designed to protect*.

Other alternatives that are under consideration are for the long term as they will require regional consensus, possible prototype studies, lengthy engineering studies, lengthy construction periods, very high implementation costs, and will have high uncertainty as a safe bypass route for fish. These may include:

- Raised tailrace channel
- Additional spillway bays
- Submerged conduits
- Baffled chute spillways
- Side channel spillways
- Pool and weir spillways
- Submerged spillway gates

Further investigations into the remaining alternatives have not been scheduled.

With regard to the development of a TMDL for temperature,based on an agreement with the States and the EPA, EPA is the lead for development of a temperature TMDL. However they will rely heavily on the Federal Agencies that administer and operate the FCRPS for the completion of the temperature TMDL.

Further progress in water temperature reductions in the Columbia and Snake rivers will require a system-wide evaluation of the Columbia and Snake River system. This will require regional, national and international forums for problem identification and problem solving. It is hoped that this Water Quality Plan will form the fundamental foundation for the TMDL implementation plans for the Columbia and Snake rivers.

1. Existing TDG TMDLs

Currently, there are three TDG TMDLs that apply to the Corps maintstem projects along the Columbia and Snake rivers:

(A) In September 2002, the lower Columbia River TDG TMDL was approved by EPA. The geographic scope of this TMDL is from the mouth of the Snake River near the Tri-Cities Washington to the mouth of the Columbia at the Pacific Ocean This TMDL can be obtained at: http://www.ecy.wa.gov/biblio/0203004.html

(B) In September 2003, the State of Washington released a TMDL for TDG in the Lower Snake River, from the confluence with the Columbia River to the confluence with the Clearwater River. This TMDL can be obtained at: http://www.ecy.wa.gov/biblio/0303020.html

(C) In July 2004, a TMDL was released for TDG for the Mid-Columbia River and Lake Roosevelt. This TMDL extended from the confluence with the Snake River to the Canadian Border. This TMDL was issued jointly by the State of Washington and the U.S. EPA. The state of Washington issued the TMDL covering the waters downstream of Grand Coulee Dam and the

U.S. EPA issued the TMDL covering all of Lake Roosevelt up to the Canadian border. This TMDL is available at: http://www.ecy.wa.gov/biblio/0403002.html

Two other current TDG TMDLS in the Columbia Basin are:

(A) In September 2004, the State of Idaho released a TMDL for TDG in the Middle Snake River from just upstream of the confluence with the Salmon River (river mile 188) to the upstream Snake River (river mile 409). This TMDL is available at: http://www.deq.Idaho.gov/water/data_reports/surface_water/tmdls/snake_river_hells_canyon/snake_river_hells_canyon.cfm

(B) An additional TMDL for TDG has been completed within the Columbia River basin, outside the geographic scope of this Plan. In December 2007, a TMDL was released for TDG for the Pend Oreille River from the Washington-Idaho border to the Washington-Canadian border. This TMDL was issued jointly by the State of Washington, the U.S. EPA, and the Kalispell Tribe of Indians. This TMDL is available at: http://www.ecy.wa.gov/biblio/0703003.html .

2. Anticipated TDG TMDLs

An additional TMDL for TDG is anticipated in the near future. A TMDL for the Clark Fork-Pend Oreille River, from the Montana-Idaho border to the Washington-Idaho border, is currently in progress and is being compiled by the State of Idaho. The Corps' Northwestern Division and the Seattle District Office is coordinating with the states of Idaho and Washington, and the Kalispel Tribe regarding actions to meet a new TMDL.

3. Existing Temperature TMDLs

The Snake River – Hells Canyon (SR-HC) TMDL document was completed in July 2003 and approved by EPA in September 2004. This document addressed the water bodies in the SR-HC Subbasin that have been placed on the "303(d) list." This TMDL is expansive in that it covers several pollutants - nutrients, dissolved oxygen toxics, temperature and TDG, and the Snake River from near Adrian, Oregon at river mile 409, downstream to the Salmon River confluence. This TMDL was a joint effort between the Idaho Department of Environmental Quality (IDEQ) and ODEQ, with participation by the EPA and local stakeholders. (IDEQ & ODEQ 2003). Details can be found at: http://www.deq.idaho.gov/water/data_reports/surface_water/tmdls/snake_river_hells_canyon/snake_river_hells_canyon.cfm

4. Anticipated Temperature TMDLs

Currently there are no approved temperature TMDLs for the mainstem lower Snake and Columbia rivers. EPA released preliminary drafts of a TMDL for water temperature in portions of the Columbia and Snake rivers in September 2002 and July 2003. The Preliminary Draft

TMDL addressed water temperature in the mainstem segments of the Columbia River from the Canadian Border to the Pacific Ocean and the Snake River from its confluence with the Salmon River to its confluence with the Columbia River. A series of public meetings were held starting July 2001, in part to discuss the methodology for allocations and potential solutions.

A workgroup was formed to develop the Columbia/Snake Temperature and TDG TMDLs. This workgroup consisted of staff from the Idaho DEQ, the ODEQ, the Washington Department of Ecology and the EPA. A number of Columbia Basin Tribes, PUDs, BPA, Corps, Reclamation, pulp and paper industries, NOAA Fisheries and USFWS also participated on the committee. EPA indicated they would issue the TMDLs for those parts of the rivers within Tribal Reservation boundaries.

The EPA Headquarters and Region 10 offices hosted a facilitated regional “Workshop on Water Quality Standards Attainment for Federal Dams in the Pacific Northwest” in Portland, Oregon during November 14-15, 2006 to discuss issues related to the attainability of State WQS at Federal dams. The workshop included presentations on water quality issues, mostly related to temperature, at Corps and Reclamation dams, and CWA tools which could apply to dams, including Use Attainability Analysis, Site Specific Criteria, waivers, and compliance schedules. Policy and technical representatives from Federal and State water quality and fisheries agencies, the Corps, Reclamation, BPA, and Tribes attended the conference.

At the workshop, EPA Region 10 stated that they wanted to re-initiate development of the Columbia/Snake Temperature TMDL, and this was supported by attendees. Since the workshop, EPA, Corps, and Reclamation representatives have coordinated on modeling approach and strategy to develop the TMDL. EPA plans to coordinate with States and Tribes to better understand the application of current state WQS for temperature to the water bodies in the TMDL.

III. ACTIONS TAKEN TO ADDRESS TDG

A. Monitoring

1. Physical Monitoring

The Corps’ Plan of Action for TDG Monitoring for 2009 can be found in Appendix D. This plan is produced annually in coordination with the Regional Forum Water Quality Team and provides greater detail about the monitoring plan. The plan includes responsibilities of the Corps’ Northwestern Division office and each of the District offices; locations of each of the TDG fixed monitoring stations, and gauge maintenance information and points of contact for each gauge. It also includes this information for other TDG fixed monitoring sites that are operated by other entities (i.e. Reclamation, Douglas County PUD, Chelan County PUD, and Grant County PUD).

In general, the water quality fixed monitoring stations are designed for the following purposes.

- To provide river operations and fisheries managers with synthesized and relevant information needed to control dissolved gas supersaturation in the river system on a real time basis.
- To determine how project releases affect downstream water quality and aquatic habitat relative to ESA Biological Opinion measures and CWA related state and tribal dissolved gas standards and waivers.
- To identify long-term changes in basin wide dissolved gas saturation levels resulting from water management decisions (structural and operational) and/or natural processes, i.e., trend monitoring.
- To provide data of known quality to enhance analytical and predictive capability of existing models/tools used to evaluate management objectives.

a. TDG Fixed Monitoring Stations - Function and Location

Since 1994, two different types of fixed water quality monitoring stations have been used to achieve the purposes outlined in 2.1.1. Forebay and tailrace monitors are maintained by the Corps of Engineers at each Corps hydroproject and record temperature, and total gas pressure. This information is coupled with operational data and reported in near real time at http://www.nwd-wc.usace.army.mil/report/total.html. The stations located downstream of the project within the tailwater channel monitor TDG production due to spillway releases and those in the forebay are intended to represent overall TDG levels approaching the next project downstream.

The tailwater instruments are located near the project and are generally positioned in the spillway releases, downstream of aerated flow and prior to complete mixing with powerhouse releases. The tailwater location often captures spill water average to peak TDG concentration. The forebay instruments are located in the forebay of the receiving pool project. The project forebay TDG monitors are intended to represent a mixed cross section in the river just upstream of the dam and can be a fair approximation of aquatic habitat conditions as defined by TDG and water temperature in that area of the pool. This information is often applied to spill management practices for the upstream project and is applied to water quality compliance monitoring as well. Because TDG concentrations measured and recorded at fixed monitoring locations downstream and within the forebay of each project are used to manage voluntary spill releases, verification of these measurements has become part of the data collection effort.

b. Results of Annual Physical Monitoring

A TDG report containing the physical gas monitoring is prepared by the Corps Reservoir Control Center annually and distributed to regional stakeholders. The States of Oregon and Washington include the annual reporting of the biological and physical monitoring as component of the state waiver and rule modification processes. Copies of these reports can be obtained at: http://www.nwd-wc.usace.army.mil/TMT/wqwebpage/mainpage.htm .

The Action Agencies, NOAA Fisheries and the Washington Department of Ecology have formed a special Fixed Monitoring Subgroup (FMSg) of the Water Quality Team to develop a plan to conduct a systematic review and evaluation of the TDG fixed monitoring system (FMS) in the forebays of all the mainstem Columbia and Snake River dams. The evaluation plan was to be developed by February 2001 and included as part of the first annual water quality improvement plan.

Tailrace Monitors - The TDG monitoring in tailraces has produced variable results associated with differences in dam operations. Operational differences cause the proportion of spill and powerhouse discharges to change in space and time. Also, the tailrace monitors are located at various distances downstream from the hydro projects. The degree to which the spillway and powerhouse flows are mixed reflects the distance from the project and the hydrodynamics of that section of the river.

In order to take these differences into account, the TMDLs for TDG in the lower Columbia and lower Snake rivers have identified the area immediately downstream of the aerated zone to be the optimal site of determination of compliance with State TDG criteria. However, due to logistical and safety problems associated with actually locating TDG gauges at this location, the TMDLs have allowed for the use of indexing. Under an indexing scenario, TDG can be measured at some alternative location, and then based on synoptic surveys, TDG levels at the end of the aerated zone can be "back-calculated." An issue that exists with respect to measuring TDG levels at the end of the aerated zone is lateral variation in TDG levels due to alternative spill patterns. Depending upon the pattern through which water is spilled through the spill bays, TDG levels at the gauge may over-estimate or may under-estimate the net production of TDG due to that spilling. This issue is currently under consideration with the Water Quality Team.

Forebay Monitors - Forebay monitors typically are located on the pier noses and other portions of hydroprojects near turbine intakes or spillways. Recent Corps investigations have demonstrated the influence of certain environmental factors on the measurements of TDG. The environmental factors include water temperature, wind, barometric pressure, solar input, and biological activity (photosynthesis). The forebay waters are subjected to these influences throughout the transit from the tailrace of the previous upriver dam. Changes in water temperature and barometric pressure can cause relative dissolved gas to change without any change in total mass of gas dissolved in the water. Sustained winds can result in off-gassing and lowering the amount of TDG in river waters as it passes through the reservoirs. The challenge for the WQT subgroup has been interpreting the TDG record and suggesting FMS locations that minimize the influence of these environmental factors and improve representation of information gathered from the stations.

At the recommendation of the FMSg, the Corps' Walla Walla District conducted a review and evaluation of forebay fixed monitoring stations within its purview. This study was conducted during the 2003 and 2004 fish spill seasons at McNary Dam and the four Lower Snake River projects, Ice Harbor Dam, Lower Monumental Dam, Little Goose Dam, and Lower

Granite Dam. The basic approach was to evaluate the information provided by the six forebay TDG fixed monitors, two at McNary and one at each of the other four projects, and assess whether these stations are generally representative of actual conditions. In addition, alternative monitor locations were evaluated and compared to the existing FMS station. The study included alternative stations near to the existing FMS station but deeper, 10-meters versus 5-meters for existing. Additional alternative sites were included in the releases on the draft tube deck, on the upstream navigation lock guide wall, and suspended from buoys upstream of the projects.

All of the existing project forebay FMS stations demonstrated problems in that each experienced thermally induced TDG pressure spikes during the test period. Some experienced spikes exceeding 5 % saturation fluctuation on a daily basis. This phenomenon is due to near field hydrodynamics coupled with vertical thermal gradients in the water column. Those monitors that are located on or near the upstream face of the powerhouse can be impacted by the down welling of the warm surface waters which result in the ambiguous and non-representative spiking of the TDG. The more significant occurrences were identified for McNary and Lower Granite dams. These sites also resulted in a relatively high number of exceedances of the water quality standard for TDG for the study period. The data suggested that the fixed monitor instruments can often report TDG values that are not representative of the forebay waters and may not meet the requirements or purpose of the FMS station.

Three primary recommendations for improving the forebay FMS operation were made as a result of this study (Carroll 2004). The first was to relocate each instrument to an area just upstream of the project not affected by down welling surface waters. This first choice was at the upstream tip of the navigation lock guide wall or any other floating structure that would not impact flows near the instrument. (Note: The Lower Granite FMS station was already positioned upstream at the end of the navigation lock guidewall). The second recommendation was to position each instrument at a depth of 12-15 meters to avoid thermal responses in the TDG pressure readings brought about by a general deepening of the warm surface layer. The third recommendation was to eliminate the McNary Oregon forebay station since the relocated Washington forebay station was considered representative of river conditions.

At the FMS subgroup meeting in December of 2003, it was recommended that the 2004 spill year be used as a transition year so that monitors were deployed for the 2004 spill season at the alternate locations in order to further evaluate and support permanent relocation to these sites in FY 2005. Following the 2004 spill season, it was agreed that the new locations would be established as permanent TDG monitoring sites.

The use of forebay TDG monitoring sites, as well as the Camas/Washougal monitoring site for spill management, is currently an issue under discussion and being examined by the AMT.

2. Biological and Physical Monitoring

a. 2008 TDG Biological Monitoring

Biological monitoring of juvenile salmonids in 2008 for GBT was conducted at Bonneville and McNary dams on the lower Columbia River, and at Rock Island Dam on the mid-Columbia River. The Snake River monitoring sites were Lower Monumental, Little Goose, and Lower Granite dams. Sampling of fish began the first full week of April at all sites and continued through August. Monitoring in the lower Snake River through the summer occurred this year because of the implementation of the Court ordered summer spill program at the Snake River collector projects. All projects sampled yearling Chinook and steelhead during the spring and switched to subyearling Chinook for monitoring during the summer when they predominated in the sample.

In 2008, a total of 12,884 juvenile salmonids were examined for GBT between April and August. A total of 89 or 0.5% showed some signs of GBT in fins or eyes. The prevalence and severity of fin signs in juvenile salmonids sampled in the lower Snake and lower Columbia rivers from 1995 to 2008 reflected changes in TDG conditions in the river from year to year. In years when it is possible to meet the TDG criteria (planned spill only) few fish are observed with signs of GBT, whereas when the TDG criteria are exceeded (during periods of forced spill or excess generation spill) increases in signs of GBT are observed.

Since the beginning of the implementation the biological monitoring of juvenile salmonids for the incidence of signs of gas bubble trauma, the annual incidence of GBT signs has ranged from 0.1% in 2001 (a low flow year) to 4.3% in 1997 (a high flow year). Over the past 5 years (2004 through 2008) the average incidence of GBT observed annually has been about 1%.

Table 2: Occurrence of Observed Gas Bubble Trauma (GBT) Since 1996

Year	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Total % Signs	3.3	3.2	1.0	0.3	0.2	0.001	0.7	1.5	0.2	0.5	1.6	2.4	0.5
% Signs Observed in FCRPS	4.2	4.3	1.6	1.4	0.2	0.1	0.7	0.5	0.2	0.1	1.4	2.9	0.7

b. Biological Monitoring Plan for 2009

Biological monitoring in 2009 for GBT will be the same as that which occurred in 2008 and previous years. Sampling would occur at Bonneville, McNary, Rock Island, Lower Granite, Little Goose and Lower Monumental Dams as outlined in the monitoring protocols (FPC, October 2008, GBT Monitoring Program Protocol for Juvenile Salmonids)

B. Modeling

Modeling of the river system is typically done to aid in decision making for fish and water quality issues. Modeling can be categorized into two main groupings. Physical models, or precision scale mock-ups of the dams, and computer based computational models designed to model in-river conditions over longer reaches than the physical models can accommodate.

1. Physical Hydraulic Models – Engineering Research and Development Center

Physical hydraulic model studies of the tailrace conditions at various dams have been constructed at the Engineering Research and Development Center (ERDC) in Vicksburg, MS. Currently, general models, or physical models of the entire dam (including forebay and tailrace geomorphology), exist for Chief Joseph Dam and every mainstem Snake and Columbia River federal fish-passing dam. In addition, sectional models, or partial cross sectional models of sections of the dams, exist for many of the spillways of these dams. Along with other objectives, these models can be used to develop spill patterns to achieve acceptable tailrace hydraulic conditions for adult fish passage, juvenile fish egress from the tailrace areas, and optimum conditions for TDG abatement. The models have also been used to test effectiveness of RSWs and spillway/powerhouse divider walls.

2. Mathematical Models

Two mathematical models (MASS1 and MASS2) have been developed by Battelle Pacific Northwest Laboratories and utilized during the Dissolved Gas Abatement Study. These models were primarily developed to provide information for the study and were not intended for use with real-time operational decisions. The models are in an expert user status. They could be used for real-time decision-making but would need further work to provide user manuals and interface. A simpler spreadsheet model (SYSTDG) has also been developed as a result of the DGAS study. This model is intended to be used as an operational decision making tool. Development is ongoing.

3. MASS 1

Mass 1 is a one dimensional, unsteady hydrodynamic and water quality model for river systems. It was developed to be used on branched (tree-like) channel systems and has been extensively applied by Battelle Pacific Northwest Division to the Columbia and Snake rivers. The model simulates cross-sectional average values. Only single values of water surface elevation, discharge, velocity, concentration, and temperatures are computed at each point in the model, at each time interval.

4. MASS 2

MASS 2 is a two- dimensional, depth-averaged hydrodynamic and transport model for river systems. It simulates time varying distributions of the depth averaged velocities, water temperature, and dissolved gas. The model is capable of simulating mixed sub-critical and super-critical flow regimes. The model is an unsteady finite-volume code that is formulated using general principles described in Patankar (1980). It uses a structured multi-block scheme on a curvilinear grid system and is formulated using orthogonal, curvilinear coordination system in a conservation form using a full-transformation in the curvilinear system by Richmond (1986).

5. SYSTDG

The Corps and Reclamation, with assistance from BPA, initiated a joint study to determine the most efficient and effective dissolved gas abatement measures at Chief Joseph and Grand Coulee dam. A System TDG model was developed (SYSTDG) in response to this study with the purpose of assessing how the Columbia River system would best benefit from proposed gas abatement measures and operational schedules. The concepts and application of the SYSTDG decision support tool were presented first to the action agencies and regional representatives in February of 2000 and to the Implementation Team in July of 2000. The 2008 BiOp calls for "continued development and use of SYSTDG for estimating TDG production to assist in real-time decision making"

The SYSTDG model predicts the TDG loading at each project in the system subject to project operations and routing of TDG pressures generated by upstream projects. The TDG pressures of spillway releases are determined from a set of empirical equations based upon observations of TDG exchange associated with highly aerated flow. The passage of water through the powerhouse does not change the TDG content and thereby retains the TDG pressures present in the forebay of a project. However, the powerhouse releases can either be entrained into the highly aerated flow below the spillway and acquire elevated TDG pressures or mix with spillway releases downstream of the highly aerated flow. The SYSTDG model predicts the average TDG levels in the forebay of a dam and TDG pressures associated with both spillway and powerhouse releases. The system is represented as a simple linked node network where TDG pressures are estimated from project operations and routed downstream to the next project. The average TDG pressures associated with project operations are routed through each pool subject to dispersion and exchange at the water surface. The influences of tributary inflows are also accommodated in this formulation. The variation in water temperature on TDG pressures can also be accounted by the model provided the net change in water temperature is provided.

C. Studies

1. Dissolved Gas Abatement Study (DGAS)

The Dissolved Gas Abatement Study (DGAS) was an element of the Columbia River Fish Mitigation Program (CRFMP) and was initiated in 1994. It was established to examine potential methods for reducing TDG supersaturation produced by spillway operations on the eight Corps' dams on the lower Snake and Columbia rivers. The DGAS was conducted in two phases. Phase I consisted of a general investigation of alternative concepts and Phase II was a continuation of analysis and evaluations based on recommendations and study plans identified in the Phase I report. The Phase I report was published in April 1996. It identified a shift from the 110% goal to a new goal designed to reduce TDG to the extent economically, technically, and biologically feasible. Phase II of the DGAS was completed in May 2002.

Near the conclusion of the DGAS Phase I, several alternatives were identified for immediate implementation. These alternatives consisted of spillway flow deflectors at Ice Harbor and John Day dams and spill pattern changes at Little Goose and Lower Monumental dams. The completion of 10 spillway flow deflectors at Ice Harbor in 1998 lowered peak TDG production levels of near 170% TDG to less than 125 % TDG for similar spill levels. The completion of 18 spillway flow deflectors at John Day in 1999 resulted in similar reductions. The new spill patterns at Little Goose and Lower Monumental resulted in TDG reductions of 5 to 10%.

For the lower Columbia and Snake River dams, the study examined a number of alternatives to reduce TDG production at Corps mainstem dams. Some of these were found to be detrimental to fish and were therefore not included in recommended future actions:

> *Based on the level of design detail, all alternatives* (see below) *appear feasible to construct and operate. The baffled chute spillway, side channel spillway, and submerged conduits alternatives have the greatest potential to achieve State and Federal water quality standards. However, the only alternatives expected to achieve safe or acceptable fish passage conditions while providing for significant gas reduction benefits include the additional/modified deflectors, powerhouse/spillway separation wall, submerged spillway gates, and additional spillway bays. These four alternatives, with operational changes to the spillway flow patterns, were recommended for evaluation in a system-wide analysis. Because of the high risk to juvenile and adult salmonids, none of the other alternatives were recommended for further consideration or development.*" (Page 11-5)

As noted, the actions that were recommended, including moving forward with the deflector optimization program which includes possible operational changes (spill pattern modification) and optimizing performance of spillway deflectors through addition of deflectors or modification of existing deflectors if necessary. Additional modifications that would further reduce the production of TDG included construction of powerhouse/spillway divider walls and additional spillway bays, and are described in more detail in below.

2. Dissolved Gas Fast Track Program

Because of the success of the gas abatement improvements at John Day and Ice Harbor dams, decisions were made to move forward with the implementation of additional flow deflectors at all projects where possible, concurrently with the Phase II DGAS. The Dissolved Gas Abatement Fast-Track (Deflector Optimization) Program was established and funded to accomplish this.

The FCRPS project modifications that resulted from the Fast-Track Deflector Optimization Program are summarized in Table 3. A more detailed discussion of modifications being considered at individual projects follows the table.

Table 3 **Summary of the Current Status of the Corps' Gas Abatement Fast-Track Deflector Optimization Program.**

Project	Pre-1995 Number of Spillbays with Deflectors	Current Number of Deflectors	Total Number of Spillbays
Bonneville	13	18	18
The Dalles	0	0	22
John Day	0	18	20
McNary	18	22	22
Ice Harbor	0	10	10
Lower Monumental	6	8	8
Little Goose	6	6[1]	8
Lower Granite	8	8	8
Chief Joseph	0	19	19

[1] A contract to construct deflectors in spill bays 1 and 8 at Little Goose is currently in progress and deflectors are scheduled to be installed and operational by 1 March 2009 bringing the total number of deflectors to 8.

D. Operations

The Corps' policy is to operate each mainstem project to meet state standards insofar as physically possible unless other overriding reasons cause deviations, such as flood control operations, powerhouse or unit outages, debris spills, special fish operations, etc. The NOAA Fisheries 2008 BiOp calls for fish spill to be provided at levels that create TDG levels exceeding 110%. The Corps operates its lower Snake and lower Columbia dams to meet the NOAA Fisheries BiOp spill of 115% TDG in the project forebays and 120% in the project tailwaters. Spring freshet river flows above the generation capacity of the FCRPS projects has occurred in the past, causing TDG levels to exceed the 115% and 120% levels for fish passage. Also, implementation of fish spill requests from fisheries agencies and tribes has resulted in TDG levels of 120% or greater. Therefore, fish spill implementation will be subject to further coordination with appropriate entities if excessive TDG levels occur or if evidence of gas bubble disease is observed in fish. The Corps will take those actions necessary to coordinate with the region and provide spill to protect ESA-listed fish, as well as resident fish species and aquatic biota. TDG levels are provided to the TMT and summarized for the year in the Corps' annual TDG Monitoring report.

Presently, the Corps plans to provide spill for juvenile fish passage at its mainstem projects to protect ESA-listed salmon species as specified by the 2008 BiOp. As provided in the

2008 BiOp, target spill levels are developed using adaptive management and may be adjusted during the fish migration season as recommended by the Technical Management Team (TMT). Continuous spill is provided at all lower Columbia and Snake river projects for spring and summer outmigrants to meet BiOp objectives.

1. Changes in Hydroproject Operations

Changing the way a hydroproject is operated (in addition to modifying total volume of spill) can also have impacts to the amount of TDG that can be produced below a dam or a series of dams. Three examples of operational changes that can be instituted include the changing of spill patterns at individual hydroprojects, shifting of power production between dams, and spill prioritization at projects.

2. Spill Priority and Operational Changes

The Corps has developed tools to estimate the amount of gas produced at incremental spill levels. At the start of each spill season (April 1 to August 31), a spill priority list is developed. When the hydraulic capacity of the hydropower system is exceeded, a spill priority system would be used to spread excess spill over the entire system to minimize high TDG levels. Spill cap flow rates are estimated on a daily basis so that forebay TDG levels are near to, but don’t exceed, 115% and tailwater TDG levels don’t exceed 120%.

Spill priority is a tool that is used in an effort to control TDG to 120%, 125%, 130% and 135% when necessary. When system wide TDG exceeds 120%, then an attempt will be made to control system wide TDG to 125%, then to 130% and so on by spilling up to the spill caps indicated for those TDG levels, at Columbia and Snake River projects as well as at Dworshak Dam.

When system wide TDG is at or below 120%, spill for fish passage would be provided up to the 120% TDG spill caps. In addition, spill could occur up to the 110% TDG spill caps at projects outside the lower Columbia River fish migration corridor: Chief Joseph, Grand Coulee, and Dworshak dams.

Spill caps for various applicable TDG levels are provided in Table 4. Spill and TDG levels are monitored and assessed daily during the spill season. Spill caps are updated as needed based on real-time TDG information and spill regimes.

Table 4 Estimated spill caps (in kcfs) corresponding to 110-135 % TDG Levels

PROJECT	TDG%	TDG%	TDG%	TDG%	TDG%	TDG%
	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 (1)	50	65	100	150	250	270
CHJ(2)	5	27	30	33	50	70
DWR(3)	37%	42%	50%	60%	70%	70%15
GCL (4)	0 20	5 25	10 30	20 75	35 120	55 170
PROJECT	TDG%	TDG%	TDG%	TDG%	TDG%	TDG%
	110	115	120	125	130	135

NOTES: (1) Limit daytime spill to 100 kcfs.
(2) Newly constructed spill deflectors have not yet been characterized with respect to TDG production.
(3) Dworshak spill caps represented as a percentage of total discharge.
(4) Assume forebay TDG at 120% (top row=outlet, when El<1260'; bottom row=spillway, when El>1260').

a. TDG Exceedances

As a consequence of conditions resulting in involuntary spill, exceedances in the TDG standards can occur throughout the year. Involuntary spill occurs either due to the physical limitations of the system, because the flow exceeds the hydraulic capacity of the power plant (can be either limited by generators or by turbines), or because the flow exceeds the available market for the power that can be generated by the plant. Because there is limited storage in the mainstem projects, there are occasions when there is no option other than to spill and the Corps has little to no control over when this might occur.

When TDG exceedances do occur, spill caps are adjusted to reduce spill in order to operate to the 115% or the 120% TDG levels during the fish migration seasons. Each exceedance is then evaluated to see if any of 12 factors (see below) contributed to the occurrence. Changes in spill are then made, daily if necessary, to adjust spill to reduce or eliminate exceedances.

The 12 criteria used to evaluate the spill level at each project during each day of the spill season are as follows:

(1) Estimated spill levels and gas caps for FCRPS projects during spring and summer.

a. Limiting Factors: gas cap, % of river flow (e.g. JDA-30% or 40%, TDA 40% of instantaneous flow), and minimum spill at BON of 75 kcfs.

(2) Oregon Rule Modification and Washington Criteria Adjustment (115% forebay, 120% tailwater)

a. Corps Check Spill Program (graphic) reviewed daily; calculate daily average TDG levels. TMT Webpage www.nwd-wc.usace.army.mil/tmt/
   1. Operations
   2. Spill Charts

b. Daily TDG Spill Decisions, numeric data of project forebay and tailwater reviewed daily and put in a Spill Log.
   1. TMT Webpage at www.nwd-wc.usace.army.mil/tmt/
   2. Related Links
   3. RCC-WQT
   4. Spill Log

c. Daily Average TDG levels reported to TMT at each meeting.
   1. TMT Webpage (see link above)
   2. Operations
   3. Spill Charts (example: May 24)
   4. Annual summary

(3) Firm Generation Commitments

a.	LWG, LGS, LMN	approximately 11.5 kcfs
b.	IHR	approximately 9.5 kcfs
b.	MCN, JDA, TDA	50 kcfs
c.	BON	30 kcfs

(4) Project-by-Project Guidance, DGAS Report. Project TDG Performance Graphs

(5) Travel Time Guidance

(6) Basic Modification Guidance:

a. Snake projects – 5 kcfs change results in about 2% change in TDG.
b. Columbia projects – 10 kcfs change results in about 2% change in TDG
c. SYSTDG guidance. Graphics based on variable spill levels based on variable inflowing TDG.

(7) Weekend Guidance: Total River Flow can significantly decrease on weekends, causing a resulting increase in TDG if the Friday spill level is not changed.

d. SSARR guidance for forecasted total river flow

(8) Monday Guidance: Beginning-of-the-Week Total River Flows on Monday increase, causing the TDG level to decrease

e. SSARR guidance for forecasted total river flow

(9) Holiday Guidance: same as weekend guidance.

(10) Degassing Guidance:

a. Winds above 10 mph enhance degassing in Columbia Gorge. http://www.wunderground.com/US/OR/Hood_River/KDLS.html Go to Personal Weather Station: Hood River (near bottom of the webpage)
f. At flows above 200 kcfs at BON, little degassing occurs between BON and Camas.
g. At flows below 200 kcfs at BON, significant degassing occurs between BON and Camas.

(11) Water Temperature Guidance: Increasing air temperatures cause TDG levels to increase about 1%. Decreasing air temperatures cause TDG levels to decrease about 1%.

(12) Spill passage test schedules cause the mass of TDG in the river to fluctuate.

3. Spill Patterns

As a general rule, optimal spill patterns for minimizing TDG production typically tend to be a flat pattern, such that there are equal amounts of spill from each spillbay across the spillway. Although these patterns may be good for managing TDG, they may not necessarily be good for ESA listed fish. The travel time, or egress, from the stilling basin of downstream migrating juvenile salmonids may be greatly increased if a spill pattern is not appropriate for a given stilling basin. In addition, adult salmonid migrations could be delayed within the system if spillway patterns are not optimized, resulting in possible impacts to successful spawning. Physical models are often used to determine appropriate spill patterns to minimize both TDG and the impacts to juvenile and adult salmon in the spillway area.

4. Power Load Redistribution

Because power generation and spill have different TDG production potential at each dam, using operational changes at a combination of dams may also help to decrease TDG system wide. For example, at Chief Joseph and Grand Coulee dams, studies have indicated that passing water through turbines at Grand Coulee adds little to no gas to the water, whereas spill at Coulee results in elevated TDG levels. As discussed in more detail below in Section F, it has been determined that full turbine operation at Coulee combined with spill at Chief Joseph, with the addition of flow deflectors would have more TDG benefits system wide rather than both spilling water and generating power at each dam.

E. Structures

Structural changes identified through studies such as DGAS, to improve water quality at hydroprojects have either been made or proposed for future implementation, include spillway flow deflectors, additional spillbays at existing dams, removable spillway weirs, and powerhouse/spillway divider walls.

1. Flow Deflectors

Spillway flow deflectors have been installed at many dams in the FCRPS. These devices are built into existing spillbays and prevent flow from plunging deep into the spillway stilling basin, tending to force higher energy flow out into the tailrace channel, and reducing the initial uptake in TDG. These structures also promote a rapid decrease in TDG by extending the boundaries of a more turbulent aerated plume. Near-field tests have shown that a significant and rapid decrease in TDG occurs within the aerated plume exiting the spillway's stilling basin due to flow deflectors.

Currently, flow deflectors do not exist at all spillbays on FCRPS dams. Installation of flow deflectors on spillbays where they do not currently exist and where it is thought to be beneficial is being considered as a viable method for reducing TDG. In addition, modifications to existing flow deflectors may also help to lower TDG. These modifications may include changing the height, length or the transition of the structure.

2. Additional Spillway Bays

Building additional spillway bays at existing dams to allow voluntary and involuntary spill releases to be more evenly distributed, with less energy dissipation requirements and associated gas uptake, was determined to be a feasible alternative from the DGAS study. By creating more spillbays, the spill release per spillbay could be effectively reduced, directly correlating to reduced TDG production. Although this option has been considered viable for TDG reduction, it is a very expensive alternative.

3. Fish Passage Improvements

The 2008 BiOp calls for meeting certain performance standards. Improvements to fish passage systems, including more fish diverted from turbines by more effective traveling or bar screens, would help to reduce the reliance on spill as a non-turbine passage route. This in turn could reduce the amount of TDG in the system.

Removable Spillway Weirs (RSW), Top Spill Weir (TSW), Adjustable Spillway Weirs (ASW) and Corner Collectors (e.g. Bonneville Dam) are examples of surface passage structures that have been installed at dams in the FCRPS. They are designed to create a surface draw from the forebay rather than the deep draw conditions of most existing spill operations. These devices are meant to safely pass a high percentage of surface-oriented fish in a relatively small amount of water. During high flow conditions, approaching standard project flood levels, the weirs can be lowered out of position down to the river bottom in the case of RSW's or removed in the case of TSWs whereby the dam can pass unimpeded the standard project flood flow. These structures provide improved passage conditions while possibly reducing the volume of water spilled with a a potential corresponding reduction in the production of TDG.

Another potential improvement is the use of a forebay guidance curtain or structure. These devices have the potential to improve or, at least maintain, spillway fish passage levels with a lesser quantity of spilled water by guiding juvenile fish toward spillway bays and away from powerhouses.

4. Powerhouse/Spillway Divider Walls

Additional improvements in TDG can be gained by construction of powerhouse/spillway divider walls. Depending on spill and powerhouse discharge flow dynamics, a portion of the powerhouse water may be entrained in the spillway flow. This situation is thought to be exacerbated by flow deflectors. The powerhouse waters are then subject to additions of dissolved gas. A divider wall is intended to prevent powerhouse water from being entrained in the spillway stilling basin and gassed up to the same levels as the water being spilled over the spillway. If the entrainment flows are reduced or prevented, then this water would be available for dilution of the gassed up spillway releases beyond the spillway flow zone.

F. Indirect Measures:

Indirect measures are those actions that improve fish passage efficiency, reduce passage times, and increase survival in order to meet BiOp biological performance standards and also result in the need for lesser amounts of spill to achieve those standards. This goal is consistent with the 2008 BiOp which calls for project spill for fish passage in a manner that minimizes TDG effects on fish.

1. Predator Removal/Abatement

The riverine ecosystems of the lower Snake and lower Columbia rivers have been significantly altered by the development of the FCRPS. This development, and associated fish management practices, has created an environment that has benefited a variety of species that prey on juvenile and adult salmonids. Studies indicate that relatively large numbers of juvenile salmonid migrants are eaten by a variety of piscivorus fish, birds, and marine mammals. The northern pikeminnow alone is responsible for the loss of approximately 8% of the juvenile salmonid migrants in the system, and gulls were estimated to take 2% of all migrants passing one Columbia River dam. Marine mammal damage has been observed on as much as 19% of the adult spring/summer chinook passing Lower Granite Dam. It is recognized that death, injury, and health problems resulting from dam and reservoir passage and the presence of non-indigenous predator species are issues that will persist regardless of how predation is managed. It also recognizes that native predators are a part of the river ecosystem. Nevertheless, it is believed that some degree of predator control is necessary and that measures to limit predation will help achieve the survival performance goals and thereby reduce the need to spill water past the dams.

2. Improved Operation and Maintenance (O&M)

Fish Facilities operations and maintenance are funded through the Corps O&M budget. The overall goal is to ensure that new and existing fish passage facilities perform at their designed level to increase both juvenile and adult fish survival. The O&M program objectives are to accomplish the following:

- Meet the increasing O&M needs of aging fish passage and spillway facilities.
- Incorporate new O&M requirements as new fish passage facilities are installed.
- Accommodate expanding annual budget requirements associated with operational changes and research needs.
- Implement preventive maintenance programs for fish passage facilities to assure long-term reliability.

3. Turbine Passage

One route of passage for juvenile and adult fish currently is through turbines, where a generally higher mortality rate occurs than through other passage routes due to direct mechanical injuries and adverse pressure changes incurred while passing through the turbine. Research and, where appropriate, implementing improved turbine designs that reduce direct and indirect mortality will continue. Additional investigations are necessary to reduce the magnitude of direct and indirect turbine mortality, as well as continued evaluations of recent advances in turbine design such as minimum gap runners. Implementation of advanced turbine design will reduce the need for spill in order to meet survival targets thereby reducing levels of TDG in the rivers.

G. Hydrosystem Projects and TDG Management: History, Status and Schedules

The historic, current status and plans for TDG management in the hydrosystem are discussed in detail in this section. Although these plans are detailed in each section, they can also be found compiled in Appendix B.

An implementation strategy for reduction of TDG can be found in the TMDL for lower Columbia River TDG. This strategy outlines a two-phased approach for reducing gas levels. The first phase is meant to identify the activities that are planned for completion in the short-term, roughly through 2010, that will help to reduce TDG levels as well as ensure the fish passage requirements as set out in the BiOp. Phase II identifies action items that are planned for the longer term, to potentially take place in 2011-2020 if warranted. In addition, the monitoring strategy for improving the reliability and accuracy of water quality monitors was outlined. In the following sections, the tables demonstrate the current status of the 28 items listed as Phase I and Phase II items in the TMDL.

Management of TDG throughout the basin is approached using various tools including the DGAS studies, the BiOp, water quality monitoring, and investigating the relationship between TDG and adult salmonid lesions known as headburn.

Table 5 Overall System TDG Management

Action Item #	Type Of Measure	Project Location	TDG Measures	Lead Agency	Status/ Year(s)	TMDL IP Phase	ESA Derived Action
Systemwide 1	Study	FCRPS	DGAS	Corps	1994-2002		✓
Systemwide 2	Activity	FCRPS	Predator Removal/Abatement	BPA	Ongoing	LC-II LS-II	✓
Systemwide 3	Operations	FCRPS	Improved O&M	Corps	Ongoing	LC-II LS-II	✓
Systemwide 4	Studies	FCRPS	Turbine Survival Program	Corps	Phase I – 2003 Phase II - 2004	LC-II LS-II	✓
Systemwide 5	Model	FCRPS	SYSTDG	Corps	2000		✓

1. Federal/Non-Federal Mid-Columbia River Projects

a. Grand Coulee Dam

Dissolved gas supersaturation is generated at Grand Coulee Dam when a portion of the total discharge is spilled through the outlet tubes or drum gates. Involuntary spill occurs an average of one in every six years at this dam. Because power plant releases transfer forebay gas levels downstream to the tailrace without introduction of additional dissolved gas, the 280,000 cfs (cubic feet/second) hydraulic capacity of power generation facilities provides an opportunity to resolve at least a portion of the TDG problem at Grand Coulee operationally, if adequate load can be developed or transferred there, for example, from Chief Joseph Dam.

Reclamation completed the "Structural Alternatives for TDG Abatement at Grand Coulee Dam" in October 2000. The study of gas abatement options at Grand Coulee Dam was conducted on a parallel track with Corps studies of Chief Joseph Dam spillway deflectors. The study evaluated gas abatement effects in the Grand Coulee tailrace with and without transfer of power loads from Chief Joseph to Grand Coulee. Results of the Reclamation study indicated that the ability to reach 110% TDG in the river below Grand Coulee is more dependent on the TDG levels present in the reservoir above than on any of the structural or operational changes studied. However, a potential structural gas abatement option at Grand Coulee could include extending and covering the existing outlet tubes to provide for submerged discharge of spill.

Following completion of the structural gas abatement study, Reclamation requested formation of a System Configuration Team/Water Quality Team subcommittee to further evaluate the Chief Joseph and Grand Coulee joint operations alternative for transferring power loads to Grand Coulee, evaluate load growth between 1997 and 2005, and project the estimated proportion of the seven day, ten year (7Q10) flow which could be used for power generation at Grand Coulee during future flood control operations. Based on the results of this study, the subcommittee concluded that for flow up to the 7Q10 value, the risk of spill at Grand Coulee could be effectively eliminated by joint operations between the two projects, involving shifting of power generation to Grand Coulee. The resulting flow increase from Grand Coulee would require spill at Chief Joseph Dam after construction of spillway flow deflectors.

b. Chief Joseph Dam

Involuntary spill occurs at Chief Joseph Dam when total river flow is greater than powerhouse capacity due to high runoff or from spring drawdown of Lake Roosevelt (Grand Coulee reservoir) for flood control, and no voluntary spill occurs because there is no anadromous fish migration past this project.

The Corps and Reclamation individually and jointly examined gas abatement opportunities at Chief Joseph and Grand Coulee dams. The Corps initiated a planning study for Chief Joseph Dam in several phases and produced several documents that can be found on the Web: http://www.nwd-wc.usace.army.mil/nws/hh/gas/index.html. Similarly, Reclamation began an evaluation of alternatives for Grand Coulee. The Corps and Reclamation also began a study of joint operation to reduce TDG loading into the Columbia.

The SYSTDG model was initially a product of the joint study alternative that was addressed in the General Reevaluation Report. The Initial Appraisal Report examined 19 alternatives that were screened to 3 by the System Configuration Team (SCT). The preferred alternative was to design and construct spillway deflectors at the project and to operate Chief Joseph jointly with Grand Coulee. Construction of the flow deflectors began in FY06 and was completed and became operational in October 2008.

c. Joint Operations of Chief Joseph Dam and Grand Coulee Dam

In late fall 2002 at a joint meeting of the Action Agencies, NOAA Fisheries, Washington Department of Ecology and the Colville Tribe a question was posed regarding the potential benefit to upper Columbia River water quality through joint operations of Grand Coulee and Chief Joseph dams in the absence of spillway deflectors at the latter project. The question was assigned to the regional forum Water Quality Team (WQT). The team's final evaluation and recommendations were provided to the Technical Management Team (TMT) in March 2003 for consideration in the TMT Water Management Plan and Spill Priority List.

The study concluded that reductions to TDG saturations could be achieved in the Mid-Columbia River through joint operations of Grand Coulee Dam and Chief Joseph Dam (Schneider 2003). The study investigated the consequences of TDG saturation in the Mid-Columbia River from spilling via the outlet works at Grand Coulee Dam versus spilling via the existing spillway (no flow deflectors) at Chief Joseph Dam. The evaluation of water quality benefits were based on reducing TDG saturation above and below Chief Joseph Dam while maintaining a constant joint power output from both projects. Joint operations of Grand Coulee and Chief Joseph was recommended to reduce the average cross-sectional TDG saturations in the Columbia River above and below Chief Joseph by taking advantage of the larger generation flow capacity of Grand Coulee and the lower average TDG loading below the Chief Joseph spillways (absent deflectors). Study results predicted that joint operations would decrease the average

TDG saturation in the Columbia River below Chief Joseph and Grand Coulee dams, but increase the localized TDG saturation in an area below the Chief Joseph spillway.

Flow deflectors construction occurred at Chief Joseph Dam from FY06 through FY08 With the completion of all deflector installation as of October 2008, joint operations with Grand Coulee are a viable alternative to reduce TDG saturations in the Columbia River. However, a post-deflector spill test will be conducted at Chief Joseph Dam to determine the TDG exchange properties during spillway discharges with flow deflectors prior to implementing any joint operations. It is anticipated that the TDG reduction in the Columbia River from joint operations will be substantially greater with flow deflectors installed on Chief Joseph Dam.

d. Federal Mid-Columbia History and Schedule

Table 6 Federal Mid-Columbia River

Action Item #	Type Of Measure	Project Location	TDG Measures	Lead Agency	Status/ Year(s)	TMDL IP Phase	ESA Derived Action
Fed Mid-C - 1	Operational	Grand Coulee	Shift spill to Chief Joseph Dam	Corps	2004	MC-I	✓
Fed Mid-C - 2	Physical	Grand Coulee	Submerge spill by extending outlet tubes	BoR	?	MC-I	
Fed Mid-C - 3	Studies	Chief Joseph	Physical Model Built	Corps	1999	MC-I	✓
Fed Mid-C - 4	Studies	Chief Joseph	Flow Deflector Models Tested	Corps	2000	MC-I	✓
Fed Mid-C - 5	Operational	Chief Joseph	Shift power generation to Grand Coulee Dam	Corps	2004	MC-I	✓
Fed Mid-C - 6	Physical	Chief Joseph	Flow Deflectors	Corps	Completed 2008	LC-I MC-I	✓

<u>2. Non-Federal Mid-Columbia Projects</u>

The non-federal Mid-Columbia projects consist of Wells Dam – Douglas County PUD, near Brewster, WA; Rocky Reach and Rock Island dams – Chelan County PUD, near Wenatchee, WA; and Wanapum and Priest Rapids Dams – Grant County PUD, near Mattawa, WA. Gas abatement measures for the PUD projects are addressed in other forums, including, but not limited to, FERC Relicensing, 401 Certifications, and the Habitat Conservation Plans (HCP). Therefore, PUD gas abatement measures are not addressed in this Plan. The PUDs will continue to be involved with the Regional Forum Water Quality Team and participate in the Mainstem Water Quality Plan Workgroup as this Plan is updated.

a. Snake River – Hells Canyon

The Hells Canyon Complex (HCC), owned and operated by Idaho Power Company (IPC) consists of the Brownlee, Oxbow, and Hells Canyon hydroelectric projects on the segment of the Snake River ranging from approximately river mile (RM) 343 to 247. Flow past Brownlee Dam, the most upstream, discharges into 12 mile long Oxbow Reservoir. Flow past Oxbow Dam discharges into 25 mile long Hells Canyon Reservoir. The river below Hells Canyon Dam is unobstructed by artificial structures until it reaches the headwaters of Lower Granite Reservoir approximately 100 miles downstream of Hells Canyon Dam.

Of the three reservoirs, Brownlee is the largest and the only one that has any significant amount of active storage and is used for system flood control. Brownlee is a long narrow reservoir 57 miles long with a maximum depth of approximately 300 feet near the dam. Total storage at full pool is 1.4 million acre-feet of water, 975,000 of which is active storage. Oxbow Dam creates a 12 mile long reservoir containing 58,000 acre-feet of storage, 11,000 acre-feet of maximum active storage. To dampen the effects of power peaking from Brownlee, Oxbow Dam is often used in conjunction with Hells Canyon Dam to moderate discharges to the lower Snake River. Hells Canyon Dam has a maximum reservoir depth of 220 feet with 167,000 acre-feet of storage, 23,000 acre-feet of that is maximum active storage associated with a stage change of 5 feet.

In 2003, IPC submitted the Final License Application (FLA) for the HCC to the FERC (IPC 2003). Following this submission IPC has responded to numerous addition information requests from FERC and continues to work with IDEQ and ODEQ to develop the finalize the application for Section 401 water quality certification. Detailed descriptions of the projects, water quality conditions related to TDG, DO and temperature are presented and discussed in detail in the FLA and 401 applications (Myers et al. 2003, IPC 2008).

Spilling at the HCC projects occurs involuntarily, usually as a result of flood control constraints or high runoff events. IPC operates the HCC to avoid spill if possible. Typically, spilling occurs between December and July in higher water years when Snake River flows exceed the project's flood storage capacity, as mandated by the Corps or the hydraulic capacity of generation turbines. Other unusual situations, including emergencies or unexpected unit outages, can induce a spill episode at any of the projects.

Spilling water at any of the three projects within the HCC can increase TDG to levels that exceed the 110% of saturation criterion. Recent (i.e. 2006) measured levels in the spill of Brownlee Dam ranged from below 110% (low spill, approximately 3000 cfs) to 140% (high spill, approximately 50,000 cfs). During high spill, relatively little dissipation downstream through Oxbow Reservoir was seen (i.e. TDG saturation reduced about 5%). It should be noted that TDG was measured at a bridge about one-half mile downstream of the spillway and do not necessarily represent levels at the edge of the aerated zone. Also, depending on spill rate, mixing of turbine and spill water can result in lower TDG levels through Oxbow reservoir than measured in Brownlee spill.

TDG levels below Oxbow Dam are typically similar to levels in Oxbow Reservoir when Brownlee is spilling. It is uncommon for Oxbow spill to occur when Brownlee is not spilling, however, if this situation occurs spill at Oxbow can result in exceedance of the 110% criterion. When Brownlee is spilling the effect of spill at Oxbow depends on incoming levels from Brownlee.

TDG levels in the Hells Canyon Dam tailwater have been measured up to 136.3% of saturation. Despite considerable variability in TDG at similar spill rates a clear relationship between spill and TDG levels exists. Nearly all rates of spill at Hells Canyon produced TDG levels exceeding 110% of saturation. Downstream dissipation of TDG lowers levels in the Snake River as water flows downstream of Hells Canyon Dam. Levels in excess of 110% of saturation have been measured at the confluence with the Salmon River (RM 188) when spilling about 20,000 cfs or greater at Hells Canyon Dam. Below the confluence with the Salmon levels in excess of 110% were not measured.

In 2006, IPC conducted a study to determine a relationship between gas bubble trauma and TDG levels within the HCC (Richter et al. 2006). Of the 20 different fish species collected, the most common were smallmouth bass (*Micropterus dolomieui*), rainbow trout (*O. mykiss*), large-scale sucker (*C. macrocheilus*), and northern pikeminnow (*Ptychocheilus oregonensis*). TDG levels associated with spill discharge ranged from 90% to 143% of saturation. No GBT symptoms were observed at TDG levels below 120%. However, severe GBT symptoms were present in fish exposed to TDG levels above 125% within the 12 hours prior to sampling.

A TDG adaptive management plan is currently proposed as part of IPC's section 401 certification process for the HCC re-licensing and includes protection, mitigation, and enhancement measures that IPC believes to be the best available technologies to reduce TDG levels. These include: (1) continuing preferential spilling of water through the Brownlee Dam upper spill gates as an early implementation measure (upper gate spill appears to reduce TDG); (2) Hells Canyon Dam sluiceway flow deflectors; (3) Brownlee Dam spillway flow deflectors, and, (4) Oxbow Dam spillway flow deflectors. The management plan is designed to be adaptive and a monitoring plan will be developed. The proposed schedule for the adaptive plan is detailed in IPC 2008.

b. Partial History of Hells Canyon TDG Events

Table 7 History of Hells Canyon TDG Events

Action Item #	Type Of Measure	Project Location	TDG Measures	Lead Agency	Status/ Year(s)	TMDL IP Phase	ESA Derived Action
Hells-C - 1	Study	Brownlee	TDG Monitoring	IPC	1997, 1998,		
Hells-C - 2	Study	Oxbow	TDG Monitoring	IPC	1997, 1998,		
Hells-C - 3	Study	Hells Canyon	TDG Monitoring	IPC	1997, 1998, 1999,		
Hells-C - 4	Study	Hells Canyon	Flow Deflectors	IPC	2000		
Hells-C - 5	Study	Brownlee	Flow Deflectors	IPC	2005		
Hells-C – 6	Study	Brownlee Oxbow, Hell Canyon	TDG and GBT Monitoring	IPC	2006		
Hells-C – 7	Study	Oxbow	Flow Deflectors	IPC	2007		

3. Lower Snake River

The Corps' Walla Walla District has an Action Planning Process focused on future fish, water quality, and planning activities.

a. Lower Granite Dam

Flow deflectors exist on all eight-spillway bays at Lower Granite Dam. These deflectors were part of the original construction of the dam and are 12.5 feet long with radiused transitions. The deflector optimization program calls for a systematic review of the existing deflector performance. One of the tasks includes conducting a physical near field gas test of the existing spillway to assess the current structural TDG performance. Additionally a removable spillway weir (RSW) was installed at Lower Granite in 2001. The 2008 BiOp spill operations for Lower Granite call for RSW flow plus minimum training flows in the spring and summer which have the potential to significantly reduce TDG levels while providing benefits to juvenile fish migration.

Additional tasks include near field TDG testing and the construction and testing of a physical hydraulic sectional model of the Lower Granite Spillway to assess potential improvements that might be made to the deflectors to improve their performance. Possible future modifications may include the addition of pier nose extensions, spillway/powerhouse divider wall and relocating the deflectors at an elevation optimized for current operation.

This study of deflector performance and possible modifications was deferred because of a lack of funding. This project is a part of the Columbia River Fish Mitigation Program (construction general funding), and the regional System Configuration Team (SCT) has not ranked this as a high priority to date.

b. Little Goose Dam

Deflectors have been constructed on six of the eight spillway bays at Little Goose Dam. These deflectors are 8 feet long and have a non-radiused transition. Deflectors with pier nose extensions in spillway bays 1 and 8 are currently under construction and will be operational for the 2009 spill season. While these deflectors have the potential to reduce TDG production, their design also considered the best geometry for safe juvenile passage.

Additionally, an ASW is currently under construction and should also be in service for the 2009 spill season in spillway bay 1.

ASW flow plus minimum training flows has the potential to significantly reduce TDG levels over current BiOp mandated spill operations while providing benefits to juvenile fish migration. Extensive general and sectional hydraulic modeling was conducted in FY08 to arrive at the best deflector geometry and spill operations to be used in conjunction with an ASW that reduces TDG production, provides a safer passage route for juvenile fish, and provides for good tailrace conditions for juveniles and adult salmon. Biological testing to determine juvenile passage effectiveness and survival under alternative spill pattern operations will be conducted after construction is complete.

In the future, a powerhouse/spillway divider wall that would provide reductions in TDG loading to downstream water bodies during spillway operations may be evaluated if the ASW, additional deflectors and modified spill operations do not appreciably reduce TDG production.

c. Lower Monumental Dam

Engineering work began on Lower Monumental Dam in FY1999 with construction of a 1:55 scale general physical hydraulic model and a 1:40 scale spillway sectional model. A contract was prepared and awarded in FY2002 for installation of two end-bay deflectors, repair of an existing deflector in Bay 2 of the spillway and repair of erosion in the existing stilling basin. This contract was completed in February 2003. Lower Monumental Dam now has a complete compliment of deflectors on all eight spillway bays. New spill patterns for juvenile fish egress and adult fish passage have been developed

A post construction near-field TDG test was conducted in 2004 to assess the performance of the newly added deflectors and revised spill pattern. The specific objectives of the field investigation were:

- Describe dissolved gas exchange processes (exchange, mixing, transport) in the Lower Monumental Dam tailwater for normal operations, bulk spill operations, and forced-spill operations with various powerhouse operations.
- Describe the TDG exchange attributes of the spillway with the additional spillway flow deflectors on spill bays 1 and 8.
- Provide recommendations for Lower Monumental Dam regarding additional operation and structural TDG abatement alternatives.
- Provide recommendations for future water quality monitoring and management policy at Lower Monumental Dam.

A few of the reports findings (Schneider et al. 2006) were:

- TDG saturation associated with spill is a function of the specific spillway discharge, and to a lesser extent tailwater depth, for both the bulk and standard spill pattern.
- There was a consistent pattern of increased TDG levels for the bulk spill pattern compared to the normal spill pattern.
- The addition of spillway flow deflectors in spill bays 1 and 8 have significantly reduced the TDG pressure generated from these spill bays.
- There is some evidence to suggest that using a bulk spill pattern with operating bays separated by non-operating bays generates a smaller TDG load.

An RSW was completed at Lower Monumental Dam and was put into service for the 2008 fish passage season. RSW flow plus minimum training flows has the potential to reduce TDG levels over current BiOp mandated spill operations while providing benefits to juvenile fish migration. Biological testing to determine juvenile passage effectiveness and survival under alternative spill pattern operations is currently ongoing

d. Ice Harbor Dam

The Ice Harbor spillway consists of 10 spillway bays, all of which now have flow deflectors. Installation of four of the ten spillway flow deflectors was completed in December 1996 and an additional four deflectors were completed in November 1997. The remaining two end-bay deflectors along with mitigative structures to correct a navigation and adult fishway impact were completed by March 1999. These flow deflectors helped to decrease the TDG. Currently, the Ice Harbor deflectors allow the largest spill flow, 105 kcfs, on the Snake River without exceeding the 120% TDG gas cap. This is a dramatic improvement in gas abatement due to deflector installation.

Improved spill patterns for adult fish passage, juvenile fish egress and TDG reductions were implemented in the spring of 1999. Additional work, which remains to be completed on Ice Harbor, includes model study work and associated reporting on the costs and benefits of installing a powerhouse/spillway divider wall. This additional work is not currently scheduled. An RSW was installed at Ice Harbor Dam in 2005. No studies have been completed to date regarding effects on downstream TDG. RSW flow plus minimum training flows has the potential to significantly reduce TDG levels over current BiOp mandated spill operations while providing benefits to juvenile fish migration.

e. Lower Snake River History and Schedule

Table 8 Lower Snake River History and Schedule

Action Item #	Type Of Measure	Project Location	TDG Measures	Lead Agency	Status/ Year(s)	TMDL IP Phase	ESA Derived Action
Lower Snake 1	Bio Study Physical – Operational	Lower Granite	Surface Bypass Collection	Corps	1995 – 2000		✓
Lower Snake 2	Study	Lower Granite	Sectional Hydraulic Model	Corps	TBD		✓
Lower Snake 3	Physical	Lower Granite	Optimize Deflectors	Corps	TBD		✓
Lower Snake 4	Study	Lower Granite	Spill Patterns	Corps	Ongoing	LC-II LS-II	✓
Lower Snake 5	Physical	Lower Granite	Pier Nose Extensions	Corps	TBD		✓
Lower Snake 6	Physical	Lower Granite	Divider Walls	Corps	TBD	LC-I LS-I	✓
Lower Snake 7	Physical – Bio Study	Lower Granite	RSW	Corps	2002 – 2007	LC-I LS-I	✓
Lower Snake 8	Bio Study	Lower Granite	Spillway Passage Survival Study	Corps	2003 – 2006	LC-I LS-I	✓
Lower Snake 9	Study	Little Goose	General Model Tests	Corps	2007-2008		✓
Lower Snake 10	Operational	Little Goose	Spill Patterns	Corps	Final Patterns TBD after TSW installation.	LC-II LS-II	✓
Lower Snake 11	Study – Physical - Operational	Little Goose	End Bay Deflectors	Corps	2009	LC-I LS-I	✓

Action Item #	Type Of Measure	Project Location	TDG Measures	Lead Agency	Status/ Year(s)	TMDL IP Phase	ESA Derived Action
Lower Snake 12	Study – Physical - Operational	Little Goose	Optimize Deflectors	Corps	TBD		✓
Lower Snake 13	Study – Physical - Operational	Little Goose	Spillway Divider Wall	Corps	TBD	LC-I LS-I	✓
Lower Snake 14	Study – Physical - Operational	Little Goose	Spillway Sectional Model Test	Corps	2008		✓
Lower Snake 15	Bio Study	Little Goose	Spill Passage Survival Studies	Corps	2004 – 2009	LC-I LS-I	✓
Lower Snake 16	Gas Test	Little Goose	Near Field Test	Corps	TBD		✓
Lower Snake 17	Physical – Bio Study	Little Goose	TSW	Corps	2009 – 2011 TSW currently under construction with in service date of March 2009	LC-II LS-II	✓
Lower Snake 18	Study	Lower Monumental	Physical Model Development	Corps	1999		✓
Lower Snake 19	Physical	Lower Monumental	End Bay deflectors	Corps	2001 – 2003	LC-I LS-1	✓
Lower Snake 20	Operational	Lower Monumental	Spill patterns	Corps	Ongoing.	LC-II LS-II	✓
Lower Snake 21	Physical	Lower Monumental	Divider Wall Report	Corps	2004	LC-I LS-I	✓
Lower Snake 22	Physical	Lower Monumental	Report on Juvenile Bypass Outfall Reloc.	Corps	2004	LC-I LS-I	✓
Lower Snake 23	Physical	Lower Monumental	Stilling Basin Repair	Corps	2001 – 2003		✓
Lower Snake 24	Bio Study	Lower Monumental	Passage/Survival	Corps	Ongoing	LC-I LS-I	✓
Lower Snake 25	Study	Lower Monumental	Extended Fish Screens	Corps	TBD	LC-II LS-II	✓

Lower Snake 26	Physical – Bio Study	Lower Monumental	RSW	Corps	2008 – 2010 RSW placed in service March 2008	LC-II LS-II	✓
Lower Snake 27	Physical	Ice Harbor	Flow Deflectors (4 deflectors)	Corps	1996	LC-I LS-I	✓
Lower Snake 28	Physical	Ice Harbor	Flow Deflectors (4 deflectors)	Corps	1997	LC-I LS-I	✓

Action Item #	Type Of Measure	Project Location	TDG Measures	Lead Agency	Status/ Year(s)	TMDL IP Phase	ESA Derived Action
Lower Snake 29	Physical	Ice Harbor	Flow Deflectors (2 deflectors)	Corps	1999	LC-I LS-I	✓
Lower Snake 30	Operational	Ice Harbor	Spill Patterns	Corps	1999 – 2006 Final Patterns TBD in conjunction with RSW operations	LC-II LS-II	✓
Lower Snake 31	Bio Study	Ice Harbor	Passage/Survival	Corps	1999 – 2005	LC-I LS-I	✓
Lower Snake 32	Physical – Bio Study – Operation	Ice Harbor	RSW	Corps	2003 – 2008	LC-II LS-II	✓
Lower Snake 33	Phys. – Study	Ice Harbor	Divider Wall	Corps	TBD	LC-I	✓

4. Clearwater River

a. Dworshak Dam

Spillway, low level regulating outlets and some turbine operations at Dworshak Dam can produce increased levels of TDG in the tailwater area of the project. TDG production at Dworshak Dam may contribute to elevated gas levels observed in the mainstem Clearwater River, at Lower Granite Dam and can be problematic for the Dworshak Fish Hatchery located immediately downstream from the dam on the North Fork Clearwater River. To examine current project TDG performance and identify and implement operational or structural methods to decrease the production of TDG to acceptable levels, the following studies and/or activities would be conducted.

Field investigations would be conducted to define performance of individual project features including the low-level outlets, turbines, and the spillway. Additional field monitoring of the mainstem Clearwater and Snake rivers above Lower Granite Dam may be needed to assess Dworshak effects. In combination with this, a hydrological analysis to define 7Q10 and probability of certain operations and discharges would need to be conducted.

The potential operational or structural changes that may alleviate or reduce production of TDG, e.g. additional turbine installation, modifications to spillway etc., would need to be evaluated and identified. Using this information, a physical sectional spillway hydraulic model would be constructed to evaluate potential structural changes to alleviate production of TDG. A technical report documenting investigations, potential solutions and associated costs would make recommendations concerning the next steps.

b. Clearwater River History and Schedule

Table 9 Clearwater River History and Schedule

Action Item #	Type Of Measure	Project Location	TDG Measures	Lead Agency	Status/ Year(s)	TMDL IP Phase	ESA Derived Action
Clearwater 1	Study	Dworshak	Identify potential methods of reducing production of TDG.	Corps	TBD – Not Currently Funded		
Clearwater 2	Physical	Dworshak	Modifications as recommended by TDG study. Modifications may include spillway modifications, Turbine Installation etc.	Corps	TBD Based on Clearwater 1		
Clearwater 3	Physical	Dworshak	Spillway Modifications	Corps	TBD		
Clearwater 4	Physical	Dworshak	Turbine Installation	Corps	TBD		
Clearwater 5	Study	Dworshak	Hydrologic Analysis	Corps	TBD		
Clearwater 6	Study	Dworshak	Model Construction	Corps	TBD		

5. Lower Columbia River

a. McNary Dam

The McNary spillway consists of 22 spillway bays, all of which have flow deflectors. Twenty of the bays were outfitted with hoists as of 2002 that allow for previously impossible, relatively instantaneous modifications to spill patterns. The spillway gates on the remaining two bays are automatically operated using gantry cranes. Physical hydraulic model studies of the tailrace conditions at McNary were conducted allowing development of new spill patterns to achieve acceptable tailrace hydraulic conditions for both adult fish passage and juvenile fish egress from the tailrace area. Deflector improvements combined with changes in spill patterns will provide benefits in reduced TDG during involuntary spill events.

Modifications to McNary Dam could include lengthening an existing training wall to protect an adjacent fish ladder entrance on the North Shore from adverse hydraulic conditions possibly impeding fish entry. Spill schedules implemented in 2003 resolved this issue through operational modifications. The effect of a powerhouse/spillway divider wall could also be investigated as a possible future measure to reduce TDG beyond that achievable by deflectors. A post-deflector construction TDG near field study is not scheduled at this time.

Studies to replace turbines at McNary Dam have been deferred indefinitely. However, in the future, a preferred replacement turbine design would pass more water through the turbine than is currently possible. Because McNary is a bottleneck for flow through the powerhouse and spill is often required due to a lack of powerhouse capacity, it is thought that with the possibility of increased turbine discharge, that decreased spill could be a long term action for helping to reduce TDG. However, spill reduction must be reconciled with the reduced juvenile fish passage and associated reduction in survival that could also be realized.

Four new hoists were installed at the McNary Spillway, however, during commissioning overload switches on these tripped out. Further review found that older hoists installed in 1974 were also operating in overload condition. Additionally, it was determined that the gantry crane lifting beams (used to operate two spillway gates) was under-designed to handle additional loads. End result was that only 16 spillway bays could be operated in 2003. Modeling work to develop a 22-bay operational spill pattern was completed but the spill pattern could not be employed because of the hoist and gantry crane problems. The spill cap at McNary was limited to 130 kcfs as a result.

For the FY 2004 spill season, the four new hoists were repositioned over the four spillway gates with the least loading. The two gantry crane lifting beams were modified to increase their capacity to 250-tons. While not providing ideal conditions, these two actions allowed for a full 22-bay spill pattern that spill season with operational constraints applied. Additionally, CRFM funded a contract for gate rehabilitation that provided for the complete rehabilitation of up to four existing gates that FY. Gates to be rehabilitated were prioritized based on the results from load testing with the gate that is responsible for the heaviest loading being rehabilitated first, the next highest loading second, and so forth. Although gate rehabilitation does reduce the hoisting load and is beneficial for Operations and Maintenance, the hoists continue to exceed capacity on breakaway loading.

The gate hoists for the remaining sixteen gates were evaluated in 2007 to determine if past operation in overload conditions has stressed any components to generate concerns which require modifications be performed. The evaluation also considered the loads from the rehabilitated gates. A report with the results of the evaluation and recommendations on hoist modifications to bring the hoists and loads into rated capacities has been drafted. These modifications will be performed with the availability and prioritization of O&M funding.

As funding is made available the goal is to rehabilitate 24 spillway gates (includes 2-spares) and re-rate the hoists and gantry cranes to allow the full 22-bay spill pattern to be used within safe operating conditions. Of the 24 spillway gates requiring rehab, four were rehabilitated under Contract DAC68-04-C-0007 and three were rehabilitated under Contract DACW68-06-C-0029. Until such time as the rehabilitation of all gates and modifications to remaining hoists are complete, the Corps' ability to ensure a 22-bay spill pattern is at risk as the probability of a failure of one or more of numerous hoists operating in overload conditions is high.

Two temporary TSWs were installed at McNary for the 2007 spill season to evaluate the potential effectiveness of surface passage structures on the spillway. Permanent surface passage structure flow plus minimum training flows has the potential to reduce TDG levels over current BiOp spill operations while providing benefits to juvenile fish migration. Biological testing to determine juvenile passage effectiveness and survival under alternative TSW configurations and spill pattern operations is currently ongoing.

b. John Day Dam

Eighteen of the 20 spillway bays at John Day Dam were modified with flow deflectors in February 1998. New spill patterns were established at that time. Endbays (bays 1 and 20) were not modified primarily due to concerns with adverse juvenile salmon egress with deflectors on these bays. A surface bypass prototype program at John Day is underway in conjunction with evaluations of alternatives to address tailrace passage survival improvements. Two spillway weirs were installed in 2008 and will be tested again in 2009. The spillway weirs have the potential to reduce turbine entrainment of juvenile fish and more efficient passage as compared to conventional spill. An alternative under consideration for tailrace passage improvements includes a spill wall or deflector on bay 20 which could also serve to separate powerhouse and spillway flows which could also serve to reduce TDG levels.

c. The Dalles Dam

The Dalles Dam was not identified as a project for immediate implementation of spillway flow deflectors at the conclusion of the DGAS Phase I, primarily due to its relatively shallow stilling basin. Deflectors may still have the potential to reduce TDG at The Dalles. However, they are currently not being considered to be a component of the spillway passage improvements under active consideration. Since completion of a spillwall in 2004 between spill bays 6 and 7, and the concentration of voluntary spill to spill bays 1 through 6, the focus of the Spillway Improvement Study (SIS) is to improve fish passage survival through effective downstream egress and reduced predation. To further this strategy, a new longer wall between bays 8 and 9 is now under construction. This is planned for completion for the 2010 passage season.

d. Bonneville Dam

Deflectors were constructed on 13 of the 18 spillbays in the early 1970s at Bonneville Dam. Deflector construction in bays 1, 2, 3, 16, 17, and 18 was completed in 2002. These deflectors were installed about seven feet lower than where the existing deflectors were located. Other spillway improvements including a movable deflector to adjust for the wide range of tailrace elevations below the project, modified spillway gate designs, and other measures are being investigated in conjunction with a future need for rehabilitation of the spillway structure.

e. Lower Columbia River History and Schedule

Table 10 Lower Columbia River History and Schedule

Action Item #	Type Of Measure	Project Location	TDG Measures	Lead Agency	Status/ Year(s)	TMDL IP Phase	ESA Derived Action
L Columbia 1	Document	System	Final TMDL-TDG	Corps	2002		✓
L Columbia 2	Physical – Operational – Study	McNary	Gate Hoists	Corps	2008		✓
Action Item #	Type Of Measure	Project Location	TDG Measures	Lead Agency	Status/ Year(s)	TMDL IP Phase	ESA Derived Action
L Columbia 3	Physical – Operational – Study	McNary	Deflector Optimization	Corps	2002		✓
L Columbia 4	Physical – Operational – Study	McNary	Spill Patterns	Corps	2002	LC-II	✓
L Columbia 5	Physical – Operational – Study	McNary	Divider Walls	Corps	TBD	LC-I	✓
L Columbia 6	Physical – Operational – Study	McNary	Training Walls	Corps	TBD		✓
L Columbia 7	Physical – Operational – Study	McNary	Modeling	Corps	2005		✓
L Columbia 8	Physical – Operational – Study	McNary	Outfall relocation	Corps	2009-2011	II	✓
L Columbia 9	Physical – Bio Study	McNary	RSW/TSW or other Surface Passage Measures	Corps	2007 - TBD		✓
L Columbia 10	Physical	McNary	Turbine Replacement	Corps	Deferred - TBD	LC-II	✓
L Columbia 11	Bio Study	McNary	Spillway Passage Survival	Corps	–Ongoing	LC-I LC-II	✓
L Columbia 12	Study	McNary	Near Field Test	Corps	Not Scheduled		✓
L Columbia 13	Physical	McNary	Endbay Deflectors	Corps	2002	LC-I	✓
L Columbia 14	Physical	John Day	Flow Deflectors (18/20)	Corps	1998 – 1999	LC-I	✓

L Columbia 15	Study - Physical	John Day	Surface Bypass Spillway Weirs Testing	Corps	2008-2009	LC-II	✓
L Columbia 16	Study-Physical	John Day	Tailrace Passage/Survival Improvement Studies	Corps	Ongoing	LC-I - II	✓
L Columbia 17	Physical	John Day	End Bay Deflectors	Corps	TBD	LC-I	✓
L Columbia 18	Physical	John Day	End Bay Deflector – Bay 1	Corps	TBD	LC-I	✓
L Columbia 19	Study – Physical	The Dalles	Spillway Improvement Study	Corps	Ongoing	LC-I	✓
L Columbia 20	Study – Physical	The Dalles	Spill Wall bays 6-7	Corps	2004	LC-I	✓
L Columbia 21	Study – Physical	The Dalles	Forebay Guidance	Corps	TBD		✓

Action Item #	Type Of Measure	Project Location	TDG Measures	Lead Agency	Status/ Year(s)	TMDL IP Phase	ESA Derived Action
L Columbia 22	Study – Physical	The Dalles	Spill Wall Bays 8-9	Corps	2010	LC-I	✓
L Columbia 23	Study - Physical –	The Dalles	Surface Bypass	Corps	Deferred		✓
L Columbia 24	Study – Physical	The Dalles	Turbine Intake Blocks	Corps	Terminated	LC-I	✓
L Columbia 25	Study – Physical	The Dalles	Sluiceway Outfall relocation	Corps	TBD	LC-I	✓
L Columbia 26	Bio Study	The Dalles	Spillway Survival Study	Corps	2010 – 2011	LC-I - II	✓
L Columbia 27	Physical	Bonneville	Spillway Deflectors (13/18)	Corps	1970's	LC-I	✓
L Columbia 28	Physical	Bonneville	Spillway Deflectors (18/18)	Corps	2002	LC-I	✓
L Columbia 29	Study - Physical	Bonneville	Spillway Modifications	Corps	Ongoing	I	✓
L Columbia 30	Study – Physical	Bonneville	PH1 Surface Bypass Sluiceway Modifications	Corps	2009-2010	LC-I	✓
L Columbia 31	Physical	Bonneville	PH2 Corner Collector	Corps	2004	LC-I	✓
L Columbia 32	Physical Study	Bonneville	Turbine Improvements (MGRs)	Corps	2010	LC-II	✓
L Columbia 33	Physical	Bonneville	PH2 FGE Improvement	Corps	2008	LC-I	✓

L Columbia 34	Bio Study	Bonneville	Passage/Survival Studies	Corps	2009-2010	LC-I - II	✓
L Columbia 35	Study	Bonneville	Near Field Testing	Corps	2002		✓
L Columbia 36	Physical	Bonneville	Improve Existing Deflectors if needed	Corps	Ongoing		✓
L Columbia 37	Operational	Bonneville	Spill Patterns	Corps	Ongoing		✓
L Columbia 38	Physical – Bio Study	Bonneville	Behavioral Guidance System Installation	Corps	Completed Install 08, Bio-Studies Ongoing		✓
L Columbia 39	Study	Bonneville	Bon Dam Spillway and Stilling Basin Alternatives Report	Corps	2009-2010		✓

H. ESA Actions Addressed

TDG that were identified in the 2000 BiOp. These include actions that are directly and indirectly related to TDG.

The Corps believes that all of the BiOp actions noted in this table are either in the process of being addressed, or have been addressed. (Please Refer to the BiOp Implementation Plan). Appendix C has a more detailed list of the RPA actions addressed in Table 11.

Table 11 TDG Reasonable and Prudent Alternatives Actions

Actions	RPA Actions						
Planning/Tools	5	54	99	130	133	198	
Gas Monitoring	131	132	141	142	143		
Gas Abatement Structures	134	135	136	139*	140		
Gas Abatement Operations	76*	139*					
Fish Passage Operations	71						
Fish Passage Evaluations	60	68	82	83	86	113	
Fish Passage Structures - RSW	72	75	77	80	138		
- Standard Bypass	62	97	98				
- Other	61	66	69	70	76*	84	108

* Indicates an RPA included in two Action categories

IV. ACTIONS TO ADDRESS WATER TEMPERATURE

A. Monitoring

1. Physical Monitoring

The Corps Plan of Action for TDG monitoring for 2009 (including temperature) can be found on the TMT website at:
http://www.nwd-wc.usace.army.mil/tmt/wq/tdg_monitoring/2009_draft.pdf

This plan is produced annually in coordination with the Fish Passage Plan and provides greater detail for those who are interested. The details of the 2009 water quality monitoring plan are in Appendix 4 of the annual Water Management Plan.

In general the water quality fixed monitoring stations are designed to provide information needed to control dissolved gas supersaturation in the river system on a real time basis, to determine how project releases affect downstream water quality, trend monitoring, and to provide data of known quality to enhance analytical and predictive capability of existing models/tools. The data collected also measures temperature, as that is an integral part of analysis for TDG.

a. TDG Fixed Monitoring Stations

Since 1994, two different types of fixed water quality monitoring stations have been used to achieve the purposes outlined in III.A.1. Forebay and tailrace monitors are maintained at each Corps hydroproject and record temperature, and total gas pressure. This information is coupled with operational data and reported in near real time at http://www.nwd-wc.usace.army.mil/tmt/wcd/tdg/months.html. In general, the stations located downstream of the project within the tailwater channel are intended to monitor spillway releases and those in the forebay are intended to be conditions representative of the total river.

The forebay instruments are located in the forebay of the receiving pool project. The project forebay monitors are intended to represent a mixed cross section in the river just upstream of the dam and can be a fair approximation of aquatic habitat conditions as defined by TDG and water temperature in that area of the pool. The tailwater instruments are located near the project and are generally positioned in the spillway releases, downstream of aerated flow and prior to complete mixing with powerhouse releases. This information is often applied to spill management practices for the upstream project and is applied to water quality compliance monitoring as well.

In addition to temperature monitors associated with TDG fixed monitoring stations, several projects include thermistor strings in the forebays that measure water temperatures at multiple depths. These monitoring strings are typically located near edge of the boat restricted zone. Data from these gages can be found at http://www.nwd-wc.usace.army.mil/tmt/documents/ops/temp/string_by_project.html

B. Mainstem Cooling Water Temperature Measures

The following tables are a list of actions that have been proposed for: (1) reducing overall river temperatures: (2) reduce site-specific temperatures in the mainstem rivers (e.g. at fish bypass systems); and (3) enhance our understanding of temperature impacts in the Columbia River Basin. These lists were developed from discussions with the Corps, Reclamation and EPA. Input was also solicited from other interested agencies and organizations. A matrix of these measures can be found in Appendix E. While these actions have been proposed, these actions by themselves or in concert may not reduce water temperatures. However, the ideas warrant discussion and some may warrant further investigation.

1. (M-1) Operate Dworshak Reservoir to Release cool water in July and August to Aid juvenile migration and reduce mainstem Snake River Water Temperatures.

a. Introduction

Dworshak Dam was completed on the North Fork Clearwater River in 1971 and the reservoir was filled in 1973. Releases of hypolimnetic and metalimnetic water warmed the lower Clearwater River in the fall, winter, and spring, and cooled the river during summer (Tiffan et al 2001). Beginning in 1992, Dworshak reservoir water as cool as 6°C has been released during July and August to decrease water temperatures in the Snake River. This action is done to provide benefits to summer migrating juvenile and adult salmonids in the lower Snake River system. The Corps of Engineers operates Dworshak Dam and implements this strategy on an annual basis with input from TMT representatives.

In Peery et al. 2002, a draft report, they estimated water temperatures in the forebay at Lower Granite Dam during summer could be decreased by 1 to 3ºC, depending on river flow and air temperature conditions, when releases from Dworshak reservoir reach 50% to 60% of Snake River flows at the dam. They also reported that these three variables were all significantly related to water temperatures recorded in the forebay of Lower Granite Dam, accounting for 72% of the variation in water temperatures using multiple linear regression analysis ($P < 0.0001$).

The following figures are meant to demonstrate the cooling effects of the Dworshak reservoir releases. The Corps understands that it is difficult to make comparisons with only a few years of data, however this is merely provided for general information.

Figure 1 demonstrates the average maximum daily temperatures of the mainstream Clearwater River near Spalding, Idaho from June to October in the time periods prior to building Dworshak Dam in 1971, after dam completion, and after the temperature augmentation measures commenced in 1992.

Figure 2 demonstrates average water temperatures as measured at the Ice Harbor scrollcase for roughly the period when dams were under construction, to the existence of Dworshak dam, to the period when Dworshak releases were being put into effect for temperature augmentation (Columbia River DART information). For comparison, a shorter data set of Lower Granite scrollcase data is provided in Figure 3 demonstrating the period when Lower Granite was built to the Dworshak flow augmentation measures commencing.

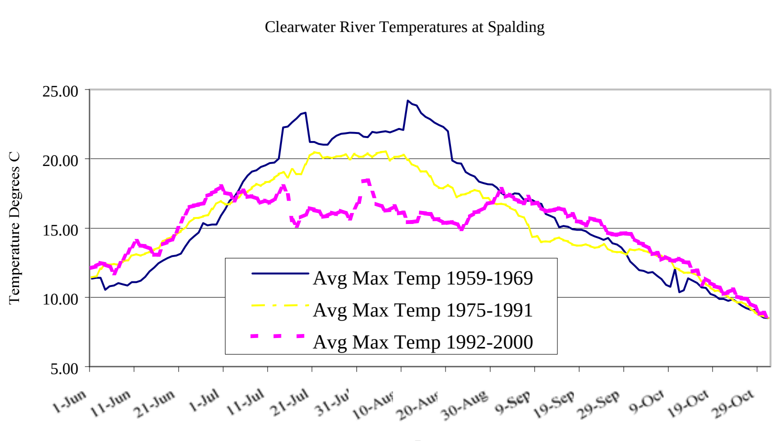

Figure 1. Clearwater average maximum daily temperatures as measured at USGS Gage at Spalding, Idaho from 1959-1969 and 1975-2000.

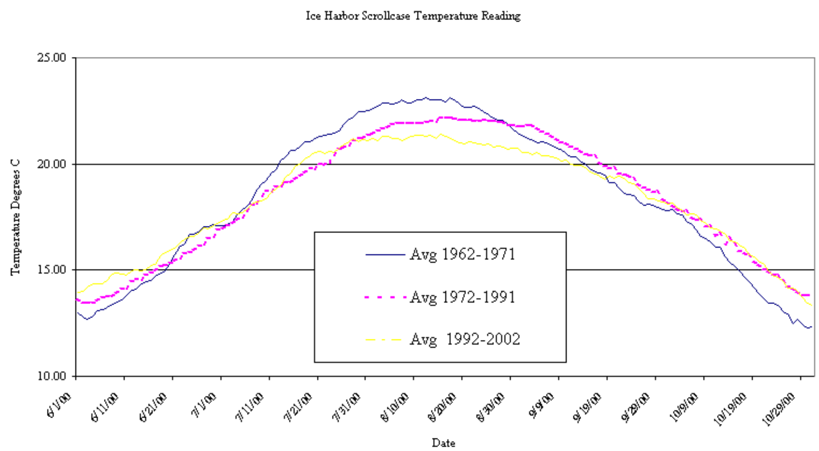

Figure 2. Water temperatures as measured at the Ice Harbor Dam Scrollcase, 1962-2002.

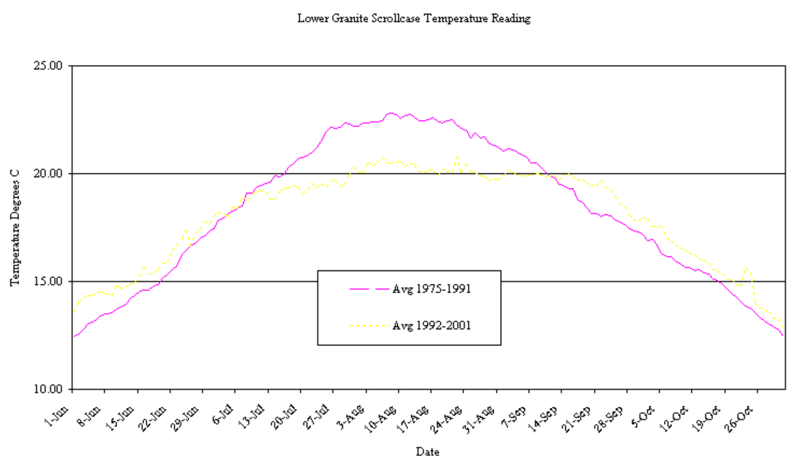

Figure 3. Water temperatures as measured at the Lower Granite Dam Scrollcase 1975-2001

b. Major Issues and Concerns

Thermal Effects of Dworshak Cold-Water Releases at Lower Granite Dam. The thermal effect of cold-water releases from Dworshak reservoir on the lower Snake River can be seen by comparing historical scrollcase temperatures with recent tailwater temperatures at Lower Granite Dam (Figure 13-4). Scrollcase temperatures were recorded at the project prior to the in-river sensors currently in-place. The within-project temperatures were recorded once or twice a day, and since the turbine intakes are located relatively deep in the water column represent near-average conditions. However, the only historic project data available shows that water temperatures were greater than 20 °C between July and the first part of September at Lower Granite Dam. Since the mid-1990s when the summer-time cold-water releases from Dworshak

Dam were initiated, the maximum tailwater temperatures at Lower Granite Dam have been 0.5 to 4.6 °C less between mid-July and mid-September.

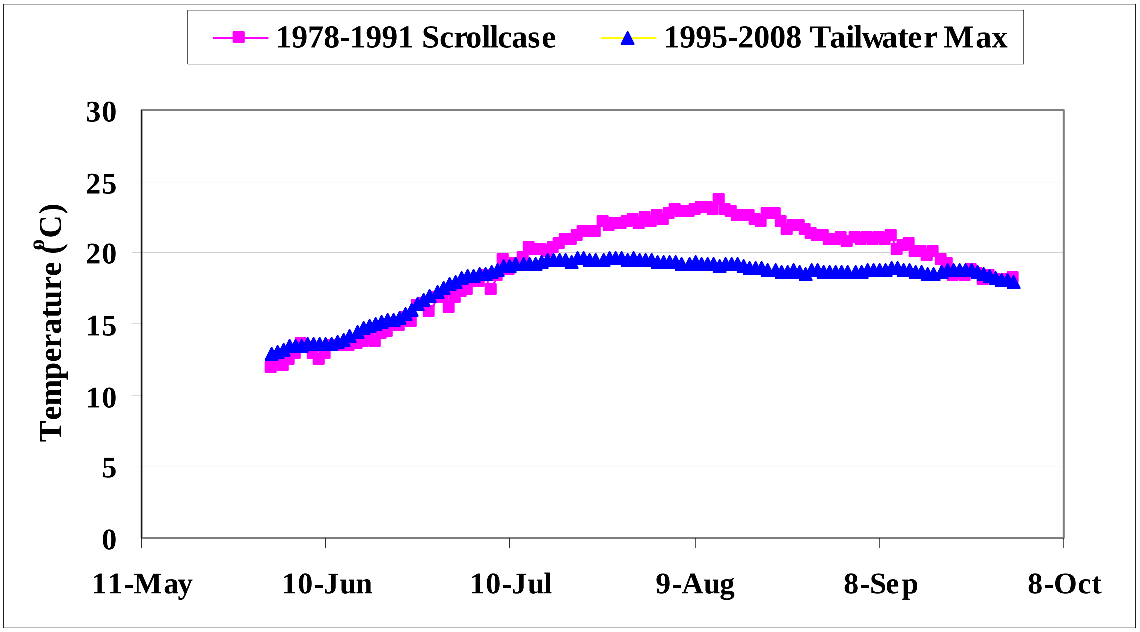

Figure 4. Comparison of historical scrollcase versus recent tailwater temperatures at Lower Granite Dam.

<u>Negative Impacts to Rearing Juvenile Fall Chinook.</u> The Nez Perce Tribe and the State of Idaho have expressed concern that releasing cold water from Dworshak could inhibit the growth rate of wild fall Chinook salmon in the Clearwater River. NMFS has attempted to manage the risks to these fish in recent years in its recommended summer flow and temperature operations at Dworshak Dam.

In some years, the lower Clearwater River produces juveniles that have a “stream-type” (Healey 1991) early life history, opposed to the typical “ocean-type” (Healey 1991) early life history of inland fall Chinook salmon. Rates of residualism as high as 85.7% in 1994 may have been an unintended result of releasing cool water from Dworshak Reservoir for summer flow augmentation. Fall Chinook typically migrate out of the Snake and Clearwater rivers by August in most years. However, large volumes (approximately 609 m3/s/d) of 8.2°C water released in July, 1994 decreased water temperatures in the lower Clearwater River from 19.5 to 8.8°C. This 10.7°C drop probably worked in concert with decreasing day length to cause the high rate of residualism by decreasing growth of parr that were still rearing and had not reached smolt size. In contrast to 1994, smaller volumes (approximately 381 m^3/s/d) of 10.8°C water released from Dworshak Reservoir in July and August of 1995 resulted in a drop from 19.8 to 13.0°C, and only 6.3% of fish from the lower Clearwater River residualized and completed seaward migration as yearling smolts. (Tiffan et al 2001)

Balancing of reservoir elevation versus augmentation. Currently, storage projects are prioritized to fill by June 30, which maximizes the rate of water to be released in July and August for salmon flows and temperature reduction flows. Drawing the reservoir down to elevation 1520 has a potential to reduce the likelihood of refill to the appropriate level by April 10.

Impacts to summer migrating adult salmonids. Concerns with adult salmonid migrations are three-fold. Delay associated with high temperature, delay associated with low temperature, and delay associated with temperature differences.

The concern of high temperature is that without Dworshak flows, migrating fish would be negatively impacted by migrating through higher water temperatures. Major and Mighell (1966) concluded that the delay of sockeye salmon near the mouth of the Okanogan River was due to a thermal block or associated factors when water temperature was greater than 21.1°C. Other reports (including Stuehrenberg et al 1993) have indicated that during the summer months, a thermal block may have occurred at the Snake River mouth near Pasco, Washington. The impacts of higher temperatures can include temperature related mortality, decreased gamete viability and/or overall loss of vigor.

Delays associated with low temperatures have been documented by adult radiotelemetry studies being conducted with NMFS and the University of Idaho. Migrating salmonids are known to harbor in mouths of tributaries that contribute cool water to the mainstem Columbia River during periods of warm temperatures. While the fish that experience these cooler temperature refugia, and continue migration, have demonstrated higher migratory success than those that do not, they are also exposed to heavier fishing pressure at these locations as well as at the mouth of the Clearwater River.

The primary issue regarding temperature differences occurs at the fish ladders themselves. Peery et al 2002 detected a delay by some fish in passing dams when temperatures exceeded 20°C and when there was a noticeable difference in temperatures between the tailrace and forebay surface, creating a sharp delineation where these two sources of water met in the fishways. Ironically, this condition was exacerbated when water was being released from Dworshak, creating a greater discrepancy between cool water temperatures deep in the reservoirs, that were subsequently passed by turbines and picked up in the tailrace, and those warmed at the forebay surface that flowed down the fishways.

Higher TDG Levels With Dworshak Discharge Rate. Spillway, low level regulating outlets and some turbine operations at Dworshak Dam can produce increased levels of TDG in the tailwater area of the project. TDG production at Dworshak Dam may contribute to elevated gas levels observed in the mainstem Clearwater River, at Lower Granite Dam and can be problematic for the Dworshak Fish Hatchery.

One of the limitations on the amount of water released from Dworshak Dam is the TDG level in the North Fork Clearwater River. Theoretically, the spillway could be used for water temperature control; however, the spillway is not used regularly because of the high TDG levels that it produces. Typically, the spillway is only used during high runoff and flood events.

The State of Idaho and the anticipated Nez Perce water quality standards are 110% of TDG saturation. The state has requested that the Corps operate to 109%, thereby accounting for potential instrumentation error. Regional acceptance of this standard and rationale has not been reached. Operating to 109% TDG limits the volume of cold water that can be drawn from Dworshak Reservoir. Some regional interests have suggested examining of releases that approach 120% TDG supersaturation. Minimum summer temperature criteria for the lower Clearwater River also have been suggested.

Bull trout. Spring discharge and cold water releases from Dworshak Dam have the potential to negatively impact bull trout, as well as their main prey species, kokanee. However, the impact to bull trout may not affect the population in the North Fork Clearwater River based on results from the study conducted by Idaho Department of Fish and Game from 2001 through 2006. A final report has not been prepared, but data from 2004 and 2005 showed only one radio-tagged bull trout was entrained through the dam during that time period. In addition to this information, the study indicated there has been an increasing trend in adult bull trout population abundance from 1,057 fish in 2002 to 1,977 in 2004.

Cold water draw downs from Dworshak normally begin after 4 July. Adult bull trout have normally left the reservoir and made their way up the North Fork to spawning streams by late May or mid-June. Therefore, it is likely that cold water draw downs have very little effect on adults. If sub-adult bull trout reside in the reservoir at this time they could be entrained if they are near the dam.

Idaho Department of Fish and Game have also been conducting a study in the Dworshak Dam forebay using strobe lights to try to scare kokanee away from the dam in order to reduce the number of these fish that are entrained. If this technique is successful it will be beneficial for bull trout that prey on kokanee in the reservoir.

c. Feasibility and Implementation

This proposed operation is the current operating standard for Dworshak Dam. Because this is a feasible measure that is implemented yearly, no further tests for the reservoir operation would be needed for temperature impacts. However, the effects of temperature on fall Chinook growth and behavior may warrant further study.

d. Schedule

This activity is currently performed yearly through the collaborative decision process of the Technical Management Team.

2. (M-2) Examine the Benefits of Drafting Dworshak an Additional 20 Feet during September to provide cool water to the mainstem.

a. Introduction

Drawing down Dworshak reservoir an additional 20 feet, as indicated in the BiOp, has the potential to: (1) reduce water temperature; (2) eliminate thermal blocks that may delay adult migration into and through the lower Snake River; and, (3) improve gamete viability of summer migrating adults. The main rationale for evaluating an additional 20-foot draft (on top of the current 80 foot drawdown) of Dworshak reservoir in September is to determine whether cooling Snake River temperatures during September would provide an adult passage benefit.

b. Major Issues and Concerns

Risk to reservoir refill and reduction of spring flows. Currently, storage projects are prioritized to fill by June 30 which maximizes the amount of water to be released in July and August for salmon flows and temperature reduction flows. The State of Idaho and Nez Perce tribe are concerned that drawing the reservoir down an additional 20 feet may reduce the potential to refill to the appropriate level, thereby reducing flows for salmon the following spring, as well as impacting in-reservoir resource values.

A 50 year hydro-regulation study was conducted in the early 2000s of Dworshak refill probability with drafting Dworshak reservoir to elevation 1500 feet. The 50-year study concluded that drafting to elevation 1500 feet would have little to no effect on reservoir refill by the end of June in subsequent years, i.e., there are only two additional refill failures at Dworshak on June 30, and the average of these three refill misses is less than 12 feet from full pool, with two of these misses within 9 feet of full pool.

Moreover, the 50-year hydro-regulation study of Dworshak refill probability indicates that the drafting of Dworshak to elevation 1500 feet has no discernable effect on reservoir refill to upper rule curve elevation by April 10, and little to no effect on spring flows.

Higher TDG Levels With Dworshak Discharge Rate. As previously discussed, operating to 109% TDG limits the volume of cold water that can be drawn from Dworshak reservoir. This may impact how water releases are made in September.

Cultural Resources. The Nez Perce tribe and is concerned with increased drawdown exposing cultural resources to potential looting or other additional damage as occurred on Lower Granite and Little Goose reservoirs during the Lower Snake River drawdown study.

Impacts to power system. Additional outflow in September would increase energy production in that month. An offsetting volume of flow would be lost from the January - June period as the reservoir storage level is returned to the same levels it would have been without the September draft. Loss of flow causes a loss of energy production in the January - June period. Generally, the net of the energy production changes over the year and the related energy revenue changes are expected to be small.

Recreation. Drawing down Dworshak reservoir an additional 20 feet in September would further limit the recreational opportunities that exist there. While the State of Idaho has stated that they do not support the further reduction of reservoir elevation, thereby reducing recreational opportunities, they have indicated that they support releases of cooler water into September.

Bull trout. Releasing water from Dworshak Dam is unlikely to negatively affect bull trout. Further drawdown of the reservoir would have a presently unknown impact on this species.

c. Feasibility and Implementation

Although the reservoir was not drawn down below elevation 1520, a field test was completed in 2002 that allowed the equivalent amount of water to be released from Dworshak Dam in September that a drawdown of an additional 20 feet from elevation 1520 to 1500 feet, would have accomplished. Although this is believed to have benefited steelhead migration at Lower Granite Dam, it did not significantly decrease the overall travel time of these fish through the lower Snake River (Peery et al 2003).

d. Schedule

Studies began in 2002 and are ongoing.

3. (M-3a) Operate the Four Lower Snake River Reservoirs between MOP and MOP+1 from April through roughly October.

a. Introduction

Lower Snake River reservoirs that are operated at lower elevations have a reduced cross-sectional area, thereby reducing surface area and exposure to solar radiation.

b. Major Issues and Concerns

Decreased Power Generation and System Flexibility. When the reservoirs behind the lower Snake River dams are lowered in elevation, the ability to produce power is reduced due to a lessening of hydraulic head on the turbine. This in turn leads to less system flexibility with respect to power generation and storage of water in the reservoirs. In addition, the inability to fluctuate the reservoir level throughout the day causes a loss in power related revenues. With a wider operating range, more of the day-average flow through the projects can be used to produce energy in the period of the day (heavy load hours) when energy values are highest.

c. Feasibility and Implementation

Discussions with the TMT will likely be held to determine if it is appropriate for operation of the reservoirs to exceed MOP where sediment has inhibited navigation if a request for this operation is tendered.

d. Schedule

Operating levels of the lower Snake River dams are discussed and implemented on a weekly basis through the TMT.

4. (M-3b) Operate the Four Lower Snake River Reservoirs below MOP, e.g. at MSL 710 or Spillway Crest from April through roughly October.

a. Introduction

The Lower Snake River Drawdown test was performed in 1992 as a result of the recommendations of the Salmon Summit in 1991. The test was designed to gather information regarding the effects of lowering existing reservoirs to potentially improve survival of downstream migrating salmonids. Lower Granite reservoir was drawn down primarily 20 feet, however to a maximum of 36 feet and Little Goose reservoir was drawn down a maximum of 12 feet. Lesser drawdown tests were not performed. Detailed information can be found in the Lower Snake River Drawdown Test Report, 1993. This report presented background material on the salmon runs and the effects of dam operations, what was accomplished during the drawdown test, including implementation procedures, monitoring and evaluation objectives and procedures, and results.

b. Major Issues and Concerns

Impacts to salmonids. Drawing the reservoir down may have a beneficial impact for juvenile salmon by increasing water velocity, thereby reducing smolt travel time through the reservoir. However, one of the major drawbacks of drawing the reservoir down only during the juvenile salmon outmigration period is that it would render the juvenile fish passage system at Lower Granite Dam unusable (if reservoir is below MOP). There are two alternatives for fish passage in the absence of the juvenile bypass systems; the turbines and the spillway. For turbine passage, the intake screens could be pulled, and fish would pass through the turbines, with most likely higher than desired mortality rates. In addition, a large number of fish would be trapped in the gatewells with no opportunity for exit, and a great number could eventually die. Although a lift tank was tested in 1994 for removal of fish from gatewells (Swan et al. 1994) to handle the number of juvenile salmon passing the project, up to 18 would need to be constructed at a very high cost. Another alternative would be to periodically dip gatewells and put fish in trucks for transporting downstream. Gatewell residence time, however, is a concern. Depending on the gatewell environment, conditions for fish can be detrimental if fish spend too much time there. The Corps does not advocate this means of fish passage during what is typically the peak of the juvenile outmigration.

If an all-spillway route were determined to be the most appropriate passage route, with no powerhouse operation, a large eddy would develop in the tailrace of the dam. A predator study (Bjornn and Piaskowski 1999) showed that during spill operations, predators in the tailrace of Lower Granite Dam tended to seek out the lower velocity areas (although this study mentioned spill on versus spill off, without regard to powerhouse operations). If an eddy is set up, it has the potential to continually cycle juvenile fish through it and constantly expose them to more predators. Although the Corps agrees that certain turbine operations could help disrupt the eddy, the 2000 NMFS FCRPS BiOp indicates that within their SIMPAS modeling efforts, they predict there would be 90-93% survival at each dam for turbine passage at the Snake River dams (FCRPS BiOp, Pages D-13-20). However, fish survival through turbines has not been measured for running at the proposed drawdown levels. Pulling fish screens and letting fish go through the turbines at the proposed forebay elevation would have unknown effects on juvenile fish survival. This operation is contrary to the agreed implementation of the Reasonable and Prudent Alternative in the 2000 FCRPS BIOP.

Without a functional juvenile bypass system, the Corps cannot transport juvenile fish around the dams. One of the benefits of transporting juvenile fish from Lower Granite Dam to downstream of Bonneville Dam is the reduced time that fish spend migrating through the hydrosystem. Fish that have been slowed down can enter saltwater smaller and less physically and physiologically developed. Because the Corps has the ability to run the bypass systems and collect fish for transportation, and deliver them to the estuary at a higher survival rate and in better physiological condition than fish traveling in-river (with a higher lipid level), drawing the reservoir down for extended periods during the juvenile fish migration seasons would most likely have a negative impact to the fish runs.

In addition, adult passage systems for operations below MOP are currently only available at Lower Granite Dam. This system, although in place, has not been tested.

Biological impacts to reservoir. Rearing areas important to fall Chinook and sturgeon would be rendered less usable if drawdown occurred on a seasonal basis. Invertebrates that use the Port of Wilma, Centennial Island and other known shallow water rearing areas would be desiccated and would provide little to no benefit to fish rearing in the area either during drawdown or after water up. However, possibly of even greater detriment, Bennett (1995) demonstrated that after the drawdown event in 1992, smallmouth bass changed their predation targets, from preying primarily on crayfish to a diet composed of more juvenile salmonids, caused by the reduction in the number of invertebrate species due to the drawdown. Because these invertebrate species would be negatively affected, species that rely on them as a primary source of food, including white sturgeon, channel catfish and other predatory species, all have the potential to change predation targets to salmonid smolts. Disruption of the food web on a *repetitive* basis would cause overall detrimental effects to the limnological characteristics of the reservoir and in turn, the smolts that would be migrating through or trying to rear in these locations on a yearly basis.

Impacts to Navigation/Hydropower/Infrastructure. Drawdown of the lower Snake River reservoirs would eliminate barging of commodities ranging from grain to petroleum to paper products for two months out of the year. In addition, lower reservoir elevations would limit the amount of power that could be produced due to reduced head on turbines, decreasing generating capacity. In the November 1995 System Operations Review EIS, partial drawdown of the four lower Snake River projects for four and a half months was analyzed (SOS-6b). The reported 50-year average annual energy production loss from that scenario was 277 average megawatts (aMW). A seven-month (April through October) operation would add significantly to the loss. During the 1992 drawdown, damage to levees, roadways, and boat basins occurred at the approximate cost of $1.3 million.

Impacts to Cultural Resources. While collecting and vandalism was recognized as a potential problem during the 1992 drawdown test, it occurred on a much greater scale than was anticipated. This happened despite extensive "anti-collecting" press releases both prior to and during the drawdown along with patrolling efforts by Corps project personnel, Washington State University and members of the Nez Perce and Umatilla Tribes. Several sites in particular received heavy impacts from collecting. This undoubtedly was due in part to their proximity to Lewiston and Clarkston. Overall, the drawdown provided access to almost every site that was monitored; sites which were inspected were marked by footprints of artifact collectors or curiosity seekers. (Corps 1993 pp. 130) In addition, between Lower Granite and Little Goose reservoirs, seven Native American burials were uncovered and required attention (Corps 1993 pp 129).

c. Feasibility and Implementation

Although various levels of drawdown have been proposed, drawing the river down when fish are passing the projects would have much the same effects on fish passage at the dams, reservoir ecology, cultural resources, and navigation. This operation has been determined by the Corps to be not feasible and is not planned for implementation.

d. Schedule

A final report was produced in December 1993 and no further action is proposed.

5. (M-3c) Operate Lower Granite Reservoir at Spillway Crest year round.

a. Introduction

As mentioned in measure M-3a, decreased reservoir elevation would lead to faster water particle travel time and reduce the overall exposure to solar radiation.

b. Major Issues and Concerns

Impacts to salmonids. The impacts to salmonids would be the same as in M-3b.

Biological impacts to reservoir. Because the permanent drawdown to spillway crest would not be done on a seasonal basis, the short term impacts to the reservoir would be substantial. However in the long term, as shallow water habitat developed in the new reservoir, it might be expected to stabilize and provide rearing habitat again for fall Chinook and other species.

Impacts to Navigation/Hydropower/Infrastructure. Permanent drawdown of the Lower Granite reservoir eliminates barging of commodities ranging from grain to petroleum to paper products year round. As with temporary drawdowns, lower reservoir elevations would limit the amount of power that could be produced due to reduced head on turbines, decreasing generating capacity. And short term damage to levees, roadways, and boat basins would again occur.

Cultural Resources. Cultural resources would be exposed to potential damage and/or looting.

c. Feasibility and Implementation

Because of the negative impacts, this operation has been determined by the Corps to be not feasible and is not planned for implementation.

d. Schedule

A final report on a Lower Granite reservoir drawdown was produced in December 1993 and a full Lower Snake River Drawdown in 2002. No further action is proposed at this time.

6. (M-3d) Remove Dams and Reservoirs

a. Introduction

Two studies have been completed to look at the effects of removing dams in the Columbia River basin (Corps 2002a and 2002b). These studies looked specifically at the four lower Snake dams and John Day Dam and are described in more detail in the sections below.

The Lower Snake River Juvenile Salmon Migration Feasibility Report / Environmental Impact Statement was finalized in 2002. This study began in 1995 as part of the recommendations of the NMFS 1995 Biological Opinion. As part of this feasibility study, the alternative of removing the lower Snake River dams was investigated. Dam breaching would create a 140-mile stretch of river with near-natural flow by removing the earthen embankment section of each dam and eliminating the reservoirs at all four lower Snake River dams. The powerhouses, spillways, and navigation locks would not be removed, but would no longer be functional. This would further reduce water surface areas exposed to solar radiation.

b. Major Issues and Concerns

The issues surrounding removal of the dams are extensive and would overwhelm this document. A brief description of the impacts to the river system is provided here, however, more extensive and detailed information can be found in the Lower Snake River Juvenile Salmon Migration Feasibility Report (USACE 2002a).

If the dams were removed, navigation locks would no longer be operational and commercial and large recreation vessel navigation in the lower Snake River would cease. No hydropower generation would occur. Other impacts include the exposing of cultural resources, an impact to the economy of the region and the reduction of water transportation to Idaho. Similarly, recreation opportunities, operation and maintenance of hatcheries and Habitat Management Units (HMUs), and other activities associated with the modification from a reservoir environment to an un-impounded lower Snake River would require important and substantial changes. Some water quality conditions such as TDG concentrations, would likely be at or near natural conditions. However, other conditions such as water temperature would still be affected by upstream conditions and/or releases. Significant sediment concentrations with increased turbidity would also occur. Although it has not been modeled, it is possible that releases of water from Dworshak Dam could be reduced if the 4 lower Snake River dams and reservoirs were removed.

c. Feasibility and Implementation

The NMFS 2000 Biological Opinion concluded that dam breaching on the lower Snake River was not necessary at that time.

Analyses of the effects of dam breaching on water temperature were based on both empirical data and model simulations. The EPA provided its water temperature modeling expertise and resources to evaluate the effects of the reservoirs using its RBM-10 model to simulate 1980, 1984, 1988, 1994, 1995, and 1997 conditions with and without the reservoirs at Snake River RM 10 (Ice Harbor) and RM 107 (Lower Granite).

Empirical data indicate that water temperatures within the study reach after dam breaching would be similar to those found on the Snake River above the existing Lower Granite pool. The maximum summer water temperature expected each year would typically reach 23°C and would exceed a 20°C benchmark temperature approximately 60 days (which are the approximate conditions found within the existing reservoirs dependent upon location and operations). Fluctuations between day and night water temperatures would typically be approximately 0.5 to 1.5°C within the water column and 1 to 2°C at the water surface. Spring water temperatures after breaching would warm faster (approximately 1 week) than the existing reservoir temperatures and would cool faster (approximately 2 weeks) in the late summer than the existing reservoir temperatures.

RBM-10 simulations indicate approximately the same maximum summer water temperatures of approximately 22 to 23°C with and without the dams. The number of days that a benchmark temperature of 20°C would be exceeded at RM 107 in an average flow year would be 46 days for the reservoir condition and 44 days for the near-natural river condition. At RM 10 the computed number of days exceeding 20°C was 57 days for the reservoir condition and 46 days for the near-natural river condition. According to RBM-10 simulations, the effect of the dams on average temperature during the hot period of the year (June through August) is minimal with temperature going from 18.9°C with the reservoirs in place to 19.1°C for a near-natural river condition.

RBM-10 simulations show greater differences in the 1994, 1995, and 1997 simulations when Dworshak Dam augmentation with cold water was used to compute temperature differences between the existing condition and the near-natural river condition. In an average flow year, the number of days the temperature exceeded 20°C at RM 107 goes from 64 with the dams to 59 without the dams.

(All preceding data was taken from Corps 2002.)

d. Schedule

A final report was released in 2002 and no further action is anticipated at this time. The 2005 and 2008 check-ins will determine if further action on this measure would need to be considered.

7. (M-3e) Draw down John Day Reservoir to spillway crest or natural river.

a. Introduction

In 2002, the Corps' Portland District published a study on the Salmon Recovery through John Day Reservoir – John Day Drawdown Phase 1 Study. Although not looking at temperature in depth, this study indicated that drawdown of the reservoir to spillway crest would reduce water particle travel time through the reservoir from 5.7 to 2.5 days, and that complete drawdown of the reservoir would result in water travel time to 0.9 day. These drawdown scenarios would be expected to decrease the amount of time that water is exposed to solar radiation, however because of the reduced volume of water, the peaks in temperature would be expected to be higher and the water in that stretch of the river would be expected to warm and cool much faster during the daily cycle. (Corps 2002b)

b. Major Issues and Concerns

Although this was not specifically a temperature related study, the recommendations that resulted in the John Day Drawdown Test-Phase I indicated that drawdown of the John Day reservoir is not supported (Corps 2002b). This conclusion was based on information that indicated drawdown would:

- do little to change the survival or recovery of listed Snake River stocks,
- have mixed results for mid-Columbia stocks,
- have significant short term impacts to wildlife in that river reach,
- cost between $2.0-4.7 billion for up front costs with $403-607 million annual costs over 100 years

<u>Impacts to salmonids.</u> Similar negative impacts to salmonids outlined in measure M-3c including primarily fish passage at the dam and through the reservoir.

<u>Biological impacts to reservoir.</u> Similar negative impacts to salmonids outlined in measure M-3c including primarily negative impacts to salmonids from reduced reservoir health.

Impacts to Navigation/Hydropower/Infrastructure. Lower reservoirs would impact navigation, power production and possibly cause damage to levees and roadways similar to what was outlined in measure M-3c.

Cultural Resources. Lower reservoirs would impact cultural resources by exposing cultural resources to damage and looting, similar to what was outlined in measure M-3c.

c. Feasibility and Implementation

The Corps has determined that this operation is not feasible because improvements for migrating juvenile anadromous fish were negligible, significant negative impacts to wildlife, and a very large cost.

d. Schedule

A final report was completed in 2000 and no further action is anticipated.

8. (M-3f) Draw down other dams to spillway crest or natural river temporarily or year round.

a. Introduction

As mentioned in measure M-3a, decreased reservoir elevation would lead to faster water particle travel time and reduce the overall exposure to solar radiation.

b. Major Issues and Concerns

Impacts to salmonids. The negative impacts to salmonids would be the same as mentioned in section M-3b and M-3c.

Biological impacts to reservoir. The negative impacts to the reservoir would be the same as mentioned in section M-3b and M-3c.

Impacts to Navigation/Hydropower/Infrastructure. The negative impacts to navigation, hydropower, and infrastructure would be the same as mentioned in section M-3b and M-3c.

Impacts to Cultural Resources. Cultural resources could be exposed to potential damage and/or looting.

c. Feasibility and Implementation

Unknown.

d. Schedule

Not applicable.

9. (M-4) Grand Coulee Powerhouse Operations.

a. Introduction

Grand Coulee Dam, a storage project, has three separate powerhouses, of which the two older ones (left and right) draw water from a full pool reservoir depth of approximately 250 feet and the newer third powerplant, which draws water from around 150 feet of depth. It is thought that having powerhouse priority for the older/deeper powerhouses would have a beneficial effect on temperatures downstream by drawing water from a lower and presumably cooler level of the reservoir.

b. Major Issues and Concerns

The newest powerhouse has the potential to release the largest volume of water downstream (210,000 cfs). Therefore, selective powerhouse use is limited to the amount of water that can be passed through the older powerhouses (90,000 cfs). To meet peak load requirements, it is necessary to operate all powerhouses, which would reduce the efficiency of this operation for temperature management. A preliminary analysis of this option, using a one-dimensional selective withdrawal model (Vermeyen, 2000) suggests that selective operation of the left, right, and third powerhouses could result in as much as a 2° C reduction in Grand Coulee tailrace temperatures during the summer stratification period. However, the one-dimensional model does not provide for determining if lower release temperatures can be sustained for more than a few days.

In addition, the stratification that occurs in Lake Roosevelt typically breaks up in September. Therefore there is no potential for cooling downstream waters after that time. This type of operation may help to lower temperatures in the summer time frame; however, it would not be able to do anything for the extended fall period of warmer temperatures as introduced by the reservoir environment.

c. Feasibility and Implementation

Reclamation is currently conducting pre-appraisal analyses of this option, and will commit to additional study and testing if preliminary analyses find it is warranted.

d. Schedule

TBD

10. (M-5a) Use or Modify Water Intakes at Storage Reservoirs for Selective withdrawal.

a. Introduction

Selective withdrawal has been demonstrated at storage reservoirs to draw cooler water from stratified levels of the reservoir and deliver it downstream. The three mainstem U.S. storage reservoirs in the subject area are Grand Coulee, Brownlee and Dworshak.

b. Major Issues and Concerns

Selective withdrawal currently exists at Dworshak reservoir. With the exception of Grand Coulee (Action Item 9b), there are no other federal projects that could reduce water temperature in the mainstem Snake and Columbia rivers. Brownlee may have the potential to draw cooler water during the earlier part of the year, however, the AA's are not aware of the extent.

c. Feasibility and Implementation

No additional action is expected on this item.

d. Schedule

Not applicable.

11. (M-5b) Determine feasibility of penstock selective withdrawal at Grand Coulee

a. Introduction

Selective withdrawal has been demonstrated at various locations to draw water from stratified levels in a reservoir and deliver it downstream. A proposed water temperature measure involves structural modification of penstocks to provide for selective water withdrawal at Grand Coulee Dam, possibly similar to a Shasta Dam design.

b. Major Issues and Concerns

Although selective withdrawal has been successful at other storage facilities with lower water exchange rates, it is uncertain if there are adequate volumes of cold water in Lake Roosevelt to provide for release of cold water for an extended period of time during the summer period of peak temperatures. The logistics of constructing such a facility to accommodate 18 penstocks in 200 feet of water is a daunting and potentially very expensive task. Preliminary cost estimates, reflecting the construction that occurred at Lake Shasta, indicate that penstock construction could cost over $300 million. Other issues to take into consideration include the potential for changing the thermal regime and productivity of resident fish stocks in Lake Roosevelt.

c. Feasibility and Implementation

Reclamation is currently conducting pre-appraisal analyses of this option, and will commit to further study and evaluation if it can be justified.

d. Schedule

If further study is justified, a 3-year study to develop a 2-dimensional water quality model to define temperature benefits, and to develop appraisal level cost information is anticipated. The need for improved bathymetric data could extend the study period by 2 years.

12. (M-5c) Hell's Canyon hydroprojects.

a. Introduction

Summer temperatures are generally elevated throughout the Snake River. Snake River inflow to Brownlee Reservoir generally exceeds 20°C for about three months in the summer. However, the duration and magnitude of temperatures over 20°C are generally less in waters below the HCC than in inflow waters. Myers et al. (2003) attributes this summer cooling to the large volume of cool water retained in Brownlee Reservoir. The cool water is retained because of the reservoir's depth and the strong summer thermal stratification of the water column. This cool water is delivered downstream through the summer because Brownlee Dam's intakes are located relatively deep in the water column (about 40 m below full pool elevation). The magnitude of flow into and out of the HCC in a year appears to affect the amount of cooling. In high-water years, like the late 1990s, when the Corps requires Brownlee Reservoir drafted for flood control, little or no summer cooling is evident. This is likely due to the fact that any accessible cool water (that is water above the intake elevation) has been removed during the spring draft. There is a trend to the summer cooling effect of the HCC in medium and low-water years. In low-water years, for example 2002 through 2004, there can be as many as 50% fewer days the temperature exceeded 20 °C below the HCC as compared to above and nearly a 7 ºC reduction in the maximum temperatures measured.

The HCC has an overall cooling effect during the summer, and also spring, since outflow waters from Hells Canyon Dam are cooler than the Snake River inflow to Brownlee Reservoir (Myers et al. 2003). This trend reverses in the fall when outflow from the HCC is warmer than inflow. In 2004, the Snake-River Hells-Canyon (SR-HC) TMDL was approved. The SR-HC TMDL issued a temperature load allocation to IPC for the salmonid spawning period (October 23 to April 15) downstream of Hells Canyon Dam (IDEQ and ODEQ 2004).

The FERC AIR WQ-2 involved investigating cool water releases from Brownlee Reservoir to address this load allocation and other objectives related to fall Chinook spawning and emergence (IPC 2005, IPC 2005a, IPC 2005b, IPC 2005c). The feasibility and effect of several temperature control devices were investigated in cooperation with agencies and using a combination of modeling efforts. Results show that the SR-HC TMDL load allocation could be met with a TCS located at Brownlee Reservoir. However, the modeling, and analysis done in conjunction with NOAA Fisheries, demonstrates that the installation and operation of a TCS at Brownlee would provide no significant benefit to fall Chinook, and in fact there is significant potential for harm to both downstream and within reservoir water quality and aquatic resources from such a structure (e.g. release of anoxic cool water, changing Brownlee thermal structure). Based on the foregoing and the results from the detailed modeling effort and analysis undertaken by IPC in cooperation with NOAA Fisheries, IPC has concluded that the preferred alternative is to not install a TCS at the HCC. IPC continues to work with IDEQ and ODEQ through the 401 process to address issues associated with the SR-HC load allocation.

b. Major Issues and Concerns

There is considerable uncertainty associated with any actions that may result in changes in Brownlee in-reservoir conditions. There are also questions of how much "cool" water there is in Brownlee, how quickly this "cool" water can regenerate itself if seasonal releases are made from the lower thermocline, and also significant questions about how far cool water releases from Brownlee are "felt" or can be measured downstream (IPC 2005c). Cool water released at Brownlee through a temperature control device can be expected to result in lowered downstream DO. Significant cool water releases would only be possible by raising the current thermocline level in Brownlee. However, this will necessarily change the entire thermal structure of the reservoir and likely move anoxic layers closer to the surface where more potential for periodic mixing would occur. Periodic mixing events could increase the potential for localized episodes of extremely low dissolved oxygen conditions throughout the water column, thereby increasing the potential of fish-kill events that currently occur infrequently.

13. (M-6) Alter the Flood Control Rule Curves

a. Introduction

System flood control operations strongly influence streamflow characteristics in the mainstem Snake and Columbia rivers. Current flood control operations routinely reduce non-damaging floods, e.g. agricultural areas, however more importantly, the risk of substantial damage as a result of peak flows of historical magnitude (e.g., the 1948 Vanport flood) is also reduced. Preliminary analysis of modifying system flood control showed that potentially much higher spring flows were possible (Corps 1997) in some years. Much of the existing flood control operation plan dates to the 1960s, and a systematic review of flood control operations has not occurred since 1991. That study was based on the fundamental premise that if rule curve modifications were made,*"that the existing flood control capability ...would remain unchanged."* Thus any substantial reduction in capacity as a result of changes in flood control criteria would also require raising levees*"a corresponding amount to compensate."* (Corps 1991)

There was the view that a broader consideration of flood control options could identify operations that would benefit the fishery without increasing the likelihood of damaging floods. The primary objective was to develop a more normative hydrograph, in the attempt to assure a relatively high proportion of migrating juvenile salmonids are "flushed" out of the river system prior to water temperatures warming up.

New stream flow prediction techniques, including Extended Stream flow Prediction (ESP) (NOAA River Forecast Center stream flow model) and remote sensing, have greatly improved since 1969. Computer improvements facilitate consideration of a broader range of alternatives and the ability to manage flood risks more closely on a real-time basis. A thorough investigation of new forecasting technologies would enhance system response and afford greater precision in system flood control operations.

b. Major Issues and Concerns

River Hydrology. Currently, storage projects are prioritized to fill by June 30 which maximizes the amount of water to be released in July and August for salmon flows and to moderate downstream river temperatures.. It is anticipated that changes to release flood control storage would likely result in more water in the spring therefore, it is anticipated that no additional benefit for reducing mainstem temperatures in the summer and fall would occur.

Historically, efforts were made to protect all developed lands from flooding by using levees, revetments, and upstream storage. These efforts have effectively disconnected rivers from their floodplains and have had both ecological and human consequences (Benner and Sedell 1997). Ecologically, diverse and integral habitats are lost when structures isolate a river from its floodplain (Ligon et al. 1995). Riparian corridor simplification is a significant cause of salmon declines (Ligon et al. 1995). Also, by cutting off upstream floodplains from the river, vast flood storage potential is lost, and floodplain development is encouraged. Thus, when large floods occur, the outcomes in terms of property damage can be more severe than would have occurred if lesser flood protection efforts had been taken and floodplain development discouraged. By examining flood damage areas and flood protection structures throughout the river corridor, opportunities to bring more connectivity to some areas of active floodplain (e.g., undeveloped land and farmland) and more effective flood protection to others (e.g., communities) could be identified. Floodplain connectivity and bank storage can be important factors in buffering stream temperatures and providing localized cool water refugia in alluvial rivers (Poole and Berman, 2001).

c. Other Concerns

The effects that changing the flood control rule curves are varied and numerous. There are concerns that if more water were used to flush fish out during the spring, decreased power production would result in the summer and fall. Biologically, pushing more water downstream during the spring, thus causing more TDG, could out weigh the benefits of flushing fish out of the system earlier

d. System Assessments

In response to the recommendation to consider a review of system flood control operations system flood control operations to benefit the Columbia River ecosystem, including salmon, the Corps conducted a reconnaissance level study, which was completed in 2006. This study was coordinated with NOAA Fisheries and the Region and based on regional input and comments received. The Corps does not anticipate further system flood control studies at this time. However, flood risk reduction in the Columbia River Basin will be further examined in the studies being developed for future discussions concerning the Columbia River Treaty

14. (M-7) Investigate cool water releases from Canadian hydro projects.

a. Introduction

There are three major mainstem dams and one major tributary dam in Canada that are all operated by BC Hydro. These dams include Keenleyside (1968), Mica (1973, power house 1977), and Revelstoke (1984) on the mainstem and Duncan (1967) on the Duncan River. Mica, Keenleyside and Duncan are three of the Canadian Columbia River treaty projects and provide 15,500,000 acre-feet of storage. Keenleyside (Arrow) Dam is 171 feet high and has roughly 7,100,000 acre-feet of storage, Mica is roughly 800 feet high with a storage capacity of 7,000,000 acre feet, and Revelstoke Dam is 575 feet high with a reservoir that extends 81 miles back to Mica Dam (but is considered run of the river). Duncan Dam has 1.4 million acre feet of storage.

Upper and Lower Arrow Lakes existed prior to the development of the storage projects. Lower Arrow Lake was 50 miles long, averaged 1 mile wide and had a maximum depth of 600 feet. In Davidson 1969, it was reported that in September of 1961 and 1962 (prior to dam completion), temperature profiles were taken in Lower Arrow Lake and these profiles indicated thermal stratification in the lake of roughly 7-8°C between the surface and 200' deep. (This was done in an attempt to determine what might be available out of Mica dam). Davidson speculated that temperature of water released through the penstocks of Mica dam in September "should average close to 47°F (8.3°C)".

However at the outlet of the lakes the temperature was 16.8°C. At Keenleyside Dam, (at the outlet of the former lake), there is little to no thermal stratification. In addition, "the surface currents through the Arrow Lakes, aided by their shallow outlets, tend to remove the warm surface waters from them in spring and summer." In the author's opinion, deep in the Upper Arrow Lake, "lies a source of cold oxygenated water that may be used to temper the river's flows at the border in September and October. Although it would be exceedingly costly to siphon this cold water from the lake, it would solve the serious problem of temperature pollution in the upper Columbia" (presumably at the international border) "at its most critical period."

b. Major Issues and Concerns

Some concerns in the Mid-Columbia with juvenile Chinook growth, adult salmon migration characteristics, impacts to resident fish stocks and cost of the project and balancing reservoir elevation with flow augmentation arte some of the potential concerns. In addition Canada may have other issues and concerns that the US agencies are not aware of.

In EPA 1971, Columbia River monthly average temperatures in August and September, 1967 were reported as being roughly 6°C at Revelstoke, B.C. and exceeding 16.5°C Well downstream from that point, at Trail, B.C. Because of this heating that can occur in that river reach, the benefits of cool water releases reaching the U.S. Columbia River could be limited.

c. Feasibility and Implementation

Unknown

d. Schedule

Unknown

15. (M-8) Investigate Banks Lake selective withdrawal to draw warm water from Lake Roosevelt.

a. Introduction

Thermal stratification in Lake Roosevelt occurs during the early summer months but later dissipates in September. A layer of warm water on the surface of the reservoir may be contributing to the overall temperature of the Middle Columbia River. It has been hypothesized that drawing water from the uppermost part of the water column at Lake Roosevelt and sending it to Banks Lake may be able to cool the mainstem Columbia River by removing the water before it mixes with cooler water downstream.

b. Major Issues and Concerns

There have not been any studies done to date regarding this type of operation of Lake Roosevelt and Banks Lake. Authorization for conducting this type of study and implementing this operation would need to be sought.

Some of the biological constraints include an unknown impact to the fish and wildlife that inhabit Banks and the Seep lakes in Eastern Washington. There currently exists various recreational fisheries and a multitude of wetlands that could be impacted by having warmer water delivered to these lakes. Also, drawing water from the water column may have impacts to fish species that currently inhabit Lake Roosevelt. Unknown impacts to kokanee, bull trout and white sturgeon may be realized with the removal of water from the photic zone of Lake Roosevelt, that area that has the highest biological productivity. Examinations of the seasonality of this operation may need to be examined.

c. Feasibility and Implementation

It is unknown if this operation would be feasible. Included in a feasibility study would be the modeling of water quality benefits/estimate costs.

d. Schedule

If ongoing pre-appraisal analyses of this alternative find that further study is justified, a 3 year investigation is anticipated to model water quality benefits and construction costs. The need for improved bathymetric data to facilitate reservoir modeling could extend the study by 2 years.

16. (M-9) Investigate Groundwater Charging to Cool Mainstem Water

a. Introduction

While the concept of artificially charging groundwater is not new (early U.S. Geological Survey interest began in 1905), it is a new concept for the effect of trying to cool water in a mainstem river. The premise of this measure is to introduce water into strategic geologic locations in the Columbia Basin in such a way that it would eventually return to the river either through upwelling in the river bottom or by flow through the banks. If water were introduced to aquifers through the colder times of the year, or if sufficient cooling was found to occur from water being in contact with the underground substrate, the river would have the potential to be cooled via these return routes.

While some small-scale diversion projects have shown to provide localized cooling and warming in small streams, the fluvial processes of areas in the lower Snake and Columbia Rivers are quite a bit more complex. A presentation was given at an American Water Resources Association conference in Portland, Oregon, 2000 and a proposal was submitted to the Bonneville Power Administration for Project 25055 - Echo Meadows Artificial Recharge Extended Groundwater and Surface Water.

b. Major Issues and Concerns

This is a novel approach at cooling river water. The following section provides a list of cautions that may or may not be pertinent to the measure. These issues are not meant to dissuade the reader from considering this issue further, however they may be useful if further investigations take place.

Columbia Basin Project. An Associated Press Article dated October 16, 2000, reported that the Pasco Basin aquifer is continually growing as a result of 50 years of seepage from irrigation projects in the region. Most of the water in the Pasco Basin can be traced to the Columbia Basin Project, the irrigation system that transformed much of Eastern Washington into productive farmland. A large portion of the seep water settled under Franklin County, mingling with "natural" water to raise the water table several hundred feet in areas. The U.S. Geological Survey linked the rising water table that resulted to septic system failures, road damage, farmland lost to ponds and landslides along the White Bluffs of the Columbia River.

The Columbia Basin Project, including Grand Coulee Dam, Banks Lake, Moses Lake and the Seep lakes are currently contributing water into the Hanford Reach of the Columbia River through bank flows. Some of these groundwater flows are expressed in the White Bluffs of the Hanford Reach, near the primary spawning areas for Fall Chinook. Unfortunately, the flow from this water is causing severe sloughing of the Bluffs (Figure 5). The sloughing in the photo is roughly 1.5 miles long by .3 miles wide. The channel of the river has been modified to the extent that the flows have been diverted towards Locke Island and have been eroding this culturally significant landmark.

In 1997, the Geological Survey published a study on the decades of seepage that looked at about half of the Pasco Basin. Among other things, it found that about 110,000 acre-feet a year has been seeping into the aquifer from irrigation water and canal seepage and that the study area had collected 5 million acre feet of water, mostly from irrigation systems -- and there could be substantially more water in the unstudied half of the basin. George Schlender, an Ecology Department official in Spokane, told the Tri-City Herald of Kennewick, "There are places that the water is very available, and available close to the surface."

This information is included to demonstrate that it is possible to introduce water into the local water table, the Columbia Basin Project is currently transferring water to the ground water, and water is coming into the Columbia River (although not what may be considered in a beneficial manner). However if there is any impact on mainstem water temperatures, it is not known. It is also meant to demonstrate that studies on performing this type of work should not be dismissed, and serious consideration given to their potential effects. The effect of providing local cool water refugia could make this an important action, providing "stepping stones" through an otherwise adverse environment.

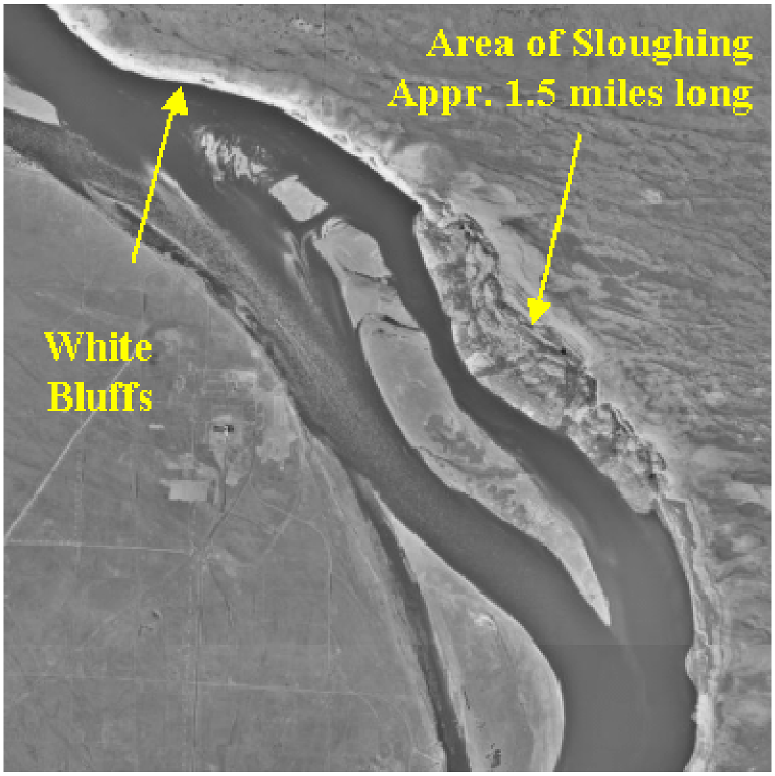

Figure 5. Aerial photo of the White Bluffs area of the Columbia River with severe sloughing of the white bluffs indicated right of center.

Substrate. According to the U.S. Department of Agriculture, suitable substrates must be present in an area of deep-water injection or those wells will clog. Because of the increasing need for underground storage of water, more artificial recharge systems will have to be constructed on finer textured soils like sandy loams to light loams, as coarse sands and gravelly materials will not always be available. Field and laboratory studies need to be carried out to predict sustainable infiltration rates for such soils and to develop design and management criteria to minimize infiltration reductions due to soil clogging. The studies range from developing and testing infiltrometer techniques with simplified correction for divergence and limited depth of wetting, to studies of fine-particle movement in the upper soil (formation of mini-clogging layers/wash-out and wash-in) and how to avoid such formation by proper design and management procedures. In addition, regarding the white bluffs, the appropriate soil types must be considered in an area prior to attempting this type of effort or it could have negative impacts.

Present Reservoir Connectivity with Groundwater. In addition to the discussions regarding how the creation of artificial reservoirs contributed to groundwater, the mainstem reservoirs also contribute to localized areas of groundwater.

In a study near Ives Island regarding Chum salmon keying in on certain areas for spawning in a side channel of the mainstem river, Geist et al 2001 reported, “We theorize that the majority of water within the floodplain aquifer at Ives Island originated from the pool behind Bonneville Dam 3.5 km upstream. This would explain the similar specific conductance values between the river and the hyporheic zone, and allow the water enough residence time to be affected by the heat-sink of the ground water system (Freeze and Cherry 1979).” At Ives Island, chum salmon typically spawn from early November to mid December and “Chum salmon spawned in areas where relatively warm water from the hyporheic zone upwelled into the river. This was indicated by the predominance of redds at sites where vertical gradients between the bed and river were positive, and bed temperatures were 7 to 11 C warmer than the river.”

Current riverbank charging in the areas of the reservoirs was demonstrated during the 1992 Lower Granite Reservoir drawdown test (Corps 1993). Sixteen groundwater wells in the vicinity of Lower Granite Dam were monitored by the USGS to determine influence of the reservoir elevation on groundwater elevation. Water elevation in 12 of the 16 monitored wells dropped between 5 and 30 feet, some of which fluctuated to the same degree of the reservoir. It is therefore logical to assume that because reservoirs are higher than water typically got during the normal spring runoff that the riverbanks are continually charged in this area.

However what is missing in the reservoir environment is the process of bank discharge and recharge in what might be considered a more normative hydrograph. What is not known is how much cooling potential was lost due to the elimination of the high and low seasonal flows versus the current high levels of reservoirs.

Although water is believed to be expressed hyporheically in the tailrace of Bonneville Dam from the Bonneville reservoir, this water is warmer during November and December than the river water, however, it is also where the chum salmon key in on spawning. This is mentioned to indicate that not all hyporheic flow will contribute cooler water and this must be considered in any potential future investigations.

Water Quality. When intentionally introducing surface water into ground water, certain water quality parameters need to be considered. If deep underwater recharge were to be performed, hydrologic challenges might include the use of models to evaluate project benefits and potential impacts, surface-water/ground-water interaction, variability and uncertainty in surface water supplies, and monitoring design and instrumentation. In addition, there may be organic and inorganic chemistry issues, changed environmental conditions and potential for mobilization of natural or man-made contaminants, and consideration for the role of emerging contaminants.

This type of water introduction may require evaluating and monitoring bacteria and viruses, including transport of viruses and bacteria, new analytical methods, and design and operation issues.

One example, in Kansas (Ziegler and Ross, 2002):

> "After artificial recharge began, median concentrations of more than 400 chemicals including chloride, atrazine, and total coliform bacteria were all substantially less than their respective drinking-water standards and similar to concentrations in the receiving ground water before recharge. However, arsenic concentrations in the one monitoring well at the test site near Halstead increased from 8 to 19 micrograms per liter and exceeded the new (2001) USEPA drinking-water standard of 10 micrograms per liter."

For a bibliography of water recharge papers and issues, please see: http://water.usgs.gov/ogw/pubs/ofr0289/epw_historical.html

c. Feasibility and Implementation

It is unknown if this operation would be feasible. Included in a feasibility study would be the need to model water quality benefits/estimate costs.

d. Schedule

Unknown

C. Site Specific Water Temperature Measures

1. (S-1) Modification of Dworshak Fish Hatchery Water Supply.

a. Introduction

Improvements to the Dworshak Fish Hatchery water supply were recommended to isolate hatchery operations from the effect of Dworshak Dam operations. These improvements were recommended because Dworshak releases could not be optimally conducted to moderate temperatures in the lower Snake River because of likely adverse effects of cold water on hatchery rearing performance. Improvements were made in 2003 to the hatchery water supply system, including upgrading the hatchery boiler system. This upgraded system can only be operated along with the hatchery reuse system, which exposes hatchery fish to significant disease risks. Consequently, these upgrades are currently not being operated.

b. Major Issues and Concerns

The need continues for using Dworshak releases for temperature moderation in the lower Snake River; while at the same time, conditions for satisfactory rearing at the hatchery are crucial, as are conditions in the Clearwater River for rearing juvenile salmon.

c. Feasibility and Implementation

Improvements to the hatchery water supply and other alternatives such as a gravity flow pipeline from Dworshak Dam to the hatchery have been proposed as a solution to the water supply and disease issues. The pipeline design would draw water from different reservoir depths to regulate temperature. The cost of this alternative is high, however, a similar water supply exists just downriver at the Clearwater Fish Hatchery and disease issues are minimal. In addition to the pipeline, other options such as a heat exchanger system (which would use warmer water from the Clearwater River to heat colder North Fork water), are currently being developed to isolate hatchery water temperatures from the effect of Dworshak Dam operations. Regional discussions are continuing with the objective of identifying feasible solutions.

2. (S-2a) Examine the temperatures in the McNary Forebay to determine if there are options to reduce water temperatures in the juvenile bypass systems

a. Introduction

McNary Dam, located near Umatilla, Oregon on the mainstem Columbia River, exhibits horizontal thermal stratification across the forebay during the warmer summer months. This is in part due to the geomorphology of the near dam area and the influence of the mixing zone of the Snake and Columbia Rivers as well as a shallow water shelf on the south side of the river near the powerhouse. During warmer times of the year, operation of turbine units closer to the warmer shallow water on the south shore of the river has a tendency to draw that water into the juvenile bypass system, causing additional stress to migrating juvenile fish within the system. This should not be misconstrued as actually cooling river water, however, rather just keeping the warmest water out of the juvenile fish facility.

Several actions have been proposed for the McNary Dam project with respect to water temperatures. One proposal includes the excavation of the reservoir on the South Shore where warm water collects. Other proposed ideas include building a levee across that shallow water area and filling in behind it to create a wetland, thereby reducing one of the sources of warming, building a sluiceway at the earthen section of the dam to draw warmer water off the top of the reservoir, delivering it to the wetlands below the dam, and drawing cooler water to that area, and installing a curtain wall upstream from the powerhouse.

b. Major Issues and Concerns

Thermal profile data have been routinely collected at McNary Dam for more than a decade. These data formed the basis for special project operations, such as north powerhouse loading operations during the summer-warm-water temperature period. The 1995 NMFS Biological Opinion required the Action Agencies to take measures to reduce the potential for reoccurrence of the 1994 thermal-related mortality observed at McNary Dam. Coutant (1999) suggested that the cause of the observed acute mortalities was a cumulative thermal dose of exposure to high temperature water received over several days (NMFS 2000c).

c. Feasibility And Implementation

North shore powerhouse loading is currently the standard operation of the McNary powerhouse. The feasibility or effectiveness of various measures to reduce thermal stress is currently unknown.

d. Schedule

Studies that began in 2000 included development of a three-dimensional computational flow dynamics model for the McNary project and forebay (Weber et al., 2006). This is a finer scaled model than is used in other areas of the basin and can be used to examine the effects of proposed configuration and operational measures being considered at McNary, and the effectiveness of those measures in mitigating thermal stress. Future model runs are contingent on available funding.

3. (S-2b) Identify water temperature cooling methods at individual projects for juvenile fish passage.

a. Introduction

While McNary Dam is a unique situation, in that geomorphology and being situated near the confluence of the Snake and Columbia rivers contributes to a horizontal thermal stratification, the other run of the river projects do not have that potential. During the temperature management operations of Dworshak Dam, there is some thermal stratification in Lower Granite Reservoir, however due to the configuration of the turbines, they draw water across the vertical range of the forebay. Therefore water entering the juvenile fish facilities is currently the coolest water available.

b. Major Issues and Concerns

None.

c. Feasibility and Implementation

Because run of river projects (with the exception of McNary Dam) do not have thermal stratification, there is not the opportunity to draw cooler water into juvenile bypass systems.

d. Schedule

Nothing is scheduled on this proposed action.

4. (S-2c) Identify methods to cool river water at individual projects.

a. Introduction

Dams that have thermal stratification in their reservoirs are typically thought to have the ability to provide cooler water from various levels within the reservoir to reaches of the river downstream. While it has been demonstrated that storage reservoirs typically have the potential to do this, run of the river reservoirs that have little to no stratification have little to no opportunity to deliver cooler water downstream.

Water temperature studies were conducted in 2002 and 2003 on the Columbia River above and below Chief Joseph Dam in part to determine the potential of using cooling water there to cool water downstream. Grand Coulee will be discussed in further detail in below. Improved monitoring and multi-dimensional modeling of the geographic scope of the plan may help to better understand the potential for these types of cooling measures.

b. Major Issues and Concerns

None.

c. Feasibility and Implementation

Run of river projects pass water as it comes to them. Because there is little to no thermal stratification at run of river projects, there is little to no potential for cooling waters of the entire river. Results of studies at Chief Joseph Dam demonstrated that there is little to no thermal stratification of Lake Rufus Woods during the periods when cooling water would be desirable. A three dimensional Computational Flow Dynamics model currently exists for the Lower Snake river and McNary reservoirs.

d. Schedule

The temperature study was conducted in 2002 and 2003 at Chief Joseph Dam. A final report was completed in 2005.

D. Research Water Temperature Measures

1. (R-1) Conduct Acoustic and Radio Data Storage Tag studies to examine migratory behavior of adults with respect to temperatures and depth. Tracking data should overlay on simulated physical conditions.

a. Introduction

Concerns with adult salmonid migrations are three-fold. Delay associated with high temperature, delay associated with low temperature, and delay associated with temperature differences. These studies are designed to enhance our understanding of the impacts of releasing cold water during a normally hot time of the year.

b. Major Issues and Concerns

There are no major concerns with this work.

c. Feasibility and Implementation

Studies using state of the art telemetry equipment were initiated in 2000 and are planed to continue through 2003. A draft report from the University of Idaho about temperature and adult migration is on the web at http://www.ets.uidaho.edu/coop/PDF%20Files/UItempreport2002.pdf

d. Schedule

Studies are currently ongoing with field investigations to be complete in 2003.

2. (R-2) Conduct Studies to examine fish behavior with respect to the water temperature in adult fish ladders.

a. Introduction

Data collected by the Corps show that water temperatures at various sections of the John Day fishways differ from 1° to 4°C at times. Effects of such differences on fish passage are unknown. Water temperatures collected in and near fishways at Ice Harbor and Lower Granite dams for the four years 1995 to 1998 routinely exceeded what we considered optimal temperatures for migrating adult salmonids. Warmest water temperatures typically occurred during July and August during the nadir between the summer and fall Chinook salmon runs and before onset of the bulk of the steelhead run. However, during warm years, such as occurred in 1998, warm water conditions can persist at the dams into October. (Peery et al. 2002) Since temperature differences of a few degrees at the confluence of the Lower Columbia and Snake Rivers and at fishways at other dams have caused adults to delay; it is logical to assume adults may behave in a similar manner when they encounter a temperature difference in or near adult fishways.

Temperature data collected in the adult fishways have shown that differences occur between the fish ladders and the tailrace temperatures. In general, these temperature differences are less than two degrees Celsius. However, during late summer in years of warm weather and low flows, a temperature difference of greater than two degrees Celsius can occur. To date, the largest temperature difference recorded is four and one-half degrees Celsius in 1992 at Lower Granite.

Water released from Dworshak reservoir was effective at cooling summertime water temperatures near the forebay surface and in fishways by an estimated 1° to 3°C at Lower Granite Dam. Cooling effects from Dworshak releases were diminished at Ice Harbor Dam because of warming and the degree of mixing that occurred as water masses moved downstream, and were difficult to quantify. Best results through the lower Snake River appeared to occur when Dworshak flows were set at 20 kcfs or more, or 50 to 60% of the Snake River flow as measured at Lower Granite Dam. There was evidence from monitoring radio-tagged adult salmon and steelhead that some fish had longer travel times into and through the lower Snake River, and some fish took longer to pass Ice Harbor and Lower Granite dams, during unfavorable water temperature conditions. There was a significant trend for later arrival of salmon and steelhead at Ice Harbor Dam during years with warm summertime water temperatures.

This project is funded from the Columbia River Fish Mitigation Program. The long-term objective of this study has been to define any problems that may exist specific to effects of fish ladder water temperature on adult salmon and steelhead and to determine feasible methods of mitigating any adverse affects.

b. Major Issues and Concerns

There are no major concerns with this work.

Regarding behavioral response to water temperatures by adult salmon and steelhead, Peery et al. (2002) reported delay by some fish in passing dams when temperatures were unfavorable, when temperatures exceeded 20°C, and when there was a noticeable difference in temperatures between the tailrace and forebay surface, creating a sharp gradient where these two sources of water met in the adult fishways. Ironically, this condition was exacerbated when water was being released from Dworshak, creating a greater discrepancy between cool water temperatures deeper in the reservoirs, that were subsequently passed by turbines and picked up in the tailrace, and those warmed at the forebay surface that flowed down the fishways.

c. Feasibility and Implementation

The work outlined in this measure is feasible and has been performed since 1994. Within the Corps' Portland District, research was conducted from 1994 through 1998 to determine whether significant temperature differences existed in the fishways of Bonneville, The Dalles and John Day dams (Dalen et al. 1999). Also, the Idaho Cooperative Fish & Wildlife Research Unit evaluated the effect of temperature on adult salmonid passage at The Dalles and John Day dams (Keefer et al. 2003). Within the Walla Walla District, the effort involves four phases, two of which have been completed. Phase 1 was a physical characterization that demonstrated significant temperature differences in the adult fishway at Lower Granite Dam during the summer (U.S. Army Corps of Engineers 2004). Such differences were progressively less significant from Little Goose to McNary dams. The Phase 2 biological evaluation suggested that ladder temperature differences slow adult fish passage at McNary and the four lower Snake River dams, especially at Lower Granite (Caudill et al. 2006). Based on these findings there is justification to proceed to Phase 3, anticipated to be completed in 2009, which will explore alternatives for providing cooler water to fish ladder exits. Phase 4 would consist of field testing one or more alternatives. Peery et al. (2002) indicated that a possible solution to this problem would be to use mixers, bubblers, or some other mechanism in the forebay to upwell cooler water to the surface near the fishway exits. Others have suggested installing a floating curtain just upstream from a fishway exit, leaving a gap between the bottom of the curtain and river bottom for cool water and fish to pass through. This cooler water could then flow down fishways and be picked up at diffuser pump intakes to moderate fishway temperatures. With this option fish would also not have to enter the warm surface water immediately upon exiting fishways. If water from deep in the reservoir is pumped directly into fishways at existing diffusers, fish will have to transition from the tailrace to the forebay temperatures near the top of the ladder. This would move the temperature gradient from where it currently exists in the transition pool to the weired section of the fishway ladders where it was found that radio-tagged salmon and steelhead advance with little hesitation. This would also have the effect of shortening the time fish are exposed to the warmest water temperatures in the fishways.

d. Schedule

Monitoring and research efforts through 2006 are complete and considered adequate for justifying further action. It is anticipated that water temperature control measures will first be implemented at Lower Granite Dam, followed by a post-construction evaluation to verify improved fish passage. Similar measures may be implemented at Little Goose and Lower Monumental dams as well. If the Phase 3 evaluation is funded and completed in 2009, Phase 4 would lead to the installation of some type of temperature control device at Lower Granite in 2010, at the earliest.

3. (R-3a) Perform additional monitoring of water temperatures in the Snake River and model investigations to evaluate alternative operations of Dworshak.

a. Introduction

Historically during some years, temperatures in the Snake River at the confluence of the Snake River to the Columbia River have created a thermal block for adult fish returning from the Columbia River to the Snake River. To help alleviate this condition, Dworshak Dam (beginning in 1991) has been releasing additional cold water to help cool the Snake River, first on an experimental basis and since 1992 as part of the operations program. Biological goals are to optimize the Snake River/Dworshak operations in an attempt to provide optimal temperature regimes (within existing authorities and other limitations) for both anadromous and resident fish. This means having sufficient information about the Snake River temperature and how fish respond to flows and temperatures to create a thermal environment that is as supportive of fish as possible.

Several studies have been completed to assess the downstream effects of cold-water releases from Dworshak Dam. The Corps contracted with Battelle's Pacific Northwest National Laboratory, to study the hydraulic conditions in the lower Snake River (Cook et al., 2006). This investigation utilized a three-dimensional computational flow dynamics model (FINS) for the reach at the confluence of the Snake and Clearwater Rivers and a two-dimensional model (CEQUAL-W2) for downstream reaches. Study recommendations included a paired fish behavior/hydraulic study and continued testing of hydrosystem operations to optimize environmental conditions for migrating salmonids in conjunction with other project purposes. The CEQUAL-W2 model was regionally accepted as the temperature model of choice as described below in Section C.

b. Major Issues and Concerns

No known negative impacts would occur, however, better understanding of the temperature augmentation of Dworshak temperature releases and other temperature issues in the lower Snake River would result.

The State of Idaho has indicated that the modeling of various operational alternatives of Dworshak releases needs to be coupled with various operational differences in the four lower Snake dams. They believe that the optimum scenario could be missed if only Dworshak releases were examined with operation of the lower four reservoirs un-changed, and vice-versa.

c. Feasibility and Implementation

Work on developing the CEQUAL-W2 model for the lower Snake River began in March 2002. A sub-group of the regional Water Quality Team (WQT) was established and co-chaired by NMFS and the Corps. The subgroup was established to assist in scoping and preparation of the plan to model the Snake River temperatures. The subgroup reported to the Water Quality Team. Participants included representatives from Battelle, BPA, CRITFC, EPA, Idaho Power Company, IDEQ, NMFS, ODEQ, Fish Passage Center, USACE and WDOE.

d. Schedule

This study began in 2002 and continued through 2008.

The major activities completed to date include:

- Establishment of team - March 8, 2002
- Initiation of data collection efforts - May 2002
- Progress report issued - September 10, 2002
- Complete review of existing data and reports
- Complete data collection/analysis and reporting
- Selection of CE-QUAL-W2 as model of choice
- Development of data collection strategy
- Implement data collection strategy
- Completion of annual reports and regional meetings

FY2002-2003 Tasks

- Screening available data
- Initiate new data collection

FY2004 Tasks

- Collect additional field data
- Select periods for model evaluation
- Complete model setup including evaluation
- Technical team review calibration and verification report.

FY2005 Tasks

- System development to operate as real-time tool for use by regional interests
- Expand to Phase 2 Geographic Scope
- Revise Data Collection as needed to support Phase 2 and other model input improvements.

FY2006 Tasks

- Expand to Phase 3 Geographic Scope with Anatone as a hard boundary on the Snake River
- Revise data collection as needed to support Phase 3 and other model inputs and improvements

FY2007 and beyond Tasks

- Implementation at Walla Walla District
- Model optimization

4. (R-3b) Improve water temperature monitoring of the Columbia River System.

a. Introduction

Agencies in the Columbia River Basin currently monitor a minimum of 40 sites for temperature with the TDG monitoring program.

b. Major Issues and Concerns

No known negative impacts are expected, but benefits include a better understanding of temperature in the rivers.

c. Feasibility and Implementation

Studies evaluating the locations of TDG monitors have been completed. Based on the recommendations made in these studies, with concurrence with the regional stakeholders, TDG monitors have been relocated. The John Day forebay gauge was relocated 2004, and the Little Goose, Lower Monumental, Ice Harbor, and McNary forebay gauges were relocated in 2005.

In addition, temperature strings have been placed in the forebays of Dworshak, Lower Granite, Little Goose, Lower Monumental, Ice Harbor, and McNary dams. These temperature strings report data to the Corps' database. The data can be viewed at http://www.nwd-wc.usace.army.mil/tmt/documents/ops/temp/string_by_project.html .

d. Schedule

These studies were completed in 2003 and gauges were relocated as recommended in 2004 and 2005.

5. (R-4) Investigate Cool Water Refugia in the Mainstem Rivers.

a. Introduction

Adult salmonids are known to stray into areas of thermal refugia, typically where tributary stream temperatures are cooler than mainstem water. Peery et al reported that fish that do use these thermal refugia, if not harvested at that location, typically have higher upstream migratory success rates than those fish that do not use those refugia. It is logical to expect that upwelling of groundwater in the mainstem Snake and Columbia Rivers may be contributing to the thermal characteristics of the river and that fish may be using these cooler water areas to use as refuge from warm temperatures.

b. Major Issues and Concerns

Mapping these would be time consuming and difficult. Locating cool water refugia from tributaries coming in would be a rather simple task, however trying to locate areas in the riverbed where cool water might be upwelling into the river system could be difficult to find in a reservoir system. Groundwater recharge and bank storage and release investigations might be needed.

c. Feasibility and Implementation

It is unknown if this operation would be feasible. Included in a feasibility study would be the modeling of water quality benefits and cost estimates, including study costs.

d. Schedule

Unknown

6. (R-5) Perform a "D-Temp" Study to Investigate Water Temperatures in the Mainstem Rivers more thoroughly (Similar to DGAS).

a. Introduction

The development of the Dissolved Gas Abatement Study (DGAS) proved very useful in developing further plans for reducing TDG. It has been proposed that a "D-Temp" (Decrease of Temperature) study be performed to provide insight into the reduction of river water temperatures. As part of a D-Temp study, detailed multidimensional models of the entire river system might be required, including possibly the CEQUALW2 model or three dimensional computational flow dynamics model.

b. Major Issues and Concerns

The CEQUALW2 model or three dimensional computational flow dynamics model would need to be expanded to encompass the geographic scope of the water quality plan. This would require a great deal of resources and time to complete.

c. Feasibility and Implementation

A report such as this is likely feasible, however, authorization, time and resources may hinder implementation.

d. Schedule

Unknown

7. (R-6) Develop a multi-dimensional model for the geographic scope of the water quality plan to determine the effectiveness of water quality measures outlined in section 7 and other measures as they arise.

a. Introduction

Because some water temperature cooling methods of the mainstem river (outlined in section 5) may be using water from thermoclines in various storage reservoirs, a multi-dimensional model would be important in determining the effectiveness of those measures towards meeting water quality standards. For example, a one-dimensional model may not be able to capture the thermal effects of drawing water off of the top of Banks Lake, however a two-dimensional model may be able to do so.

A model currently exists that may be able to meet the requirements outlined under this measure. CE-QUAL-W2 (W2), a two-dimensional model developed by the U.S. Army Corps of Engineers Waterways Experiment Station, has been used throughout North America (http://smig.usgs.gov/SMIC/model_pages/cequalw2.html) including in the lower Snake River, the Spokane River, the Tualatin River, Columbia Slough and the Snake River downstream of Brownlee Dam to the mouth of the Salmon River.

Currently a three-dimensional computational flow dynamics model exists for selected reaches of the Lower Snake and McNary reservoirs. This model was primarily designed to simulate the effects of cool water releases from Dworshak Dam and water temperatures through the powerhouse.

b. Major Issues and Concerns

Further development of this model to the international border on the Columbia and downstream of Bonneville Dam may be difficult to attain due to funding and time constraints.

c. Feasibility and Implementation

It is feasible to develop CE-QUAL-W2; however, time and money constraints may hinder implementation.

d. Schedule

Unknown

8. (R-7) Investigate the thermal relationships between fish health and temperature exposure

a. Introduction

High water temperatures have been linked to stress and disease in fish. It is important to acquire a better base of information to understand the sources of fish disease and mortality at the lower Columbia and lower Snake River dams during critical fish migration periods and high temperature events. This information could be used to better understand the effect of high water temperature on juvenile fish survival.

b. Major Issues and Concerns

Although a proposal was submitted to the Corps of Engineers for performing work on this topic, the SRWG indicated that this proposal would not meet the BiOp recommendations. Further discussions between the Walla Walla District Corps of Engineers and Portland NOAA Fisheries are in progress to develop a study plan for submission to the Studies Review Work Group.

c. Feasibility and Implementation

Feasibility phase.

d. Schedule

Unknown

E. ESA Actions Addressed

The 2000 BiOp contained actions to benefit listed anadromous salmonids, including some water quality actions e at the Federal hydroelectric projects. Table 12 represents a list of actions related to water temperatures that were identified in the 2000 BiOp.

Table 12 2000 BiOp RPA actions being addressed by this Water Quality Plan

Type of Measures	RPA Actions				
Operational	19*	20	34*	35	
Construction	33				
Research/Monitoring/Modeling	114	115*	141*	142	143

* Indicates that the proposed temperature measures would yield only partial fulfillment of the RPA

All of the BiOp actions noted in this table are either in the process of being addressed, or have been addressed. (Please Refer to the BiOp Implementation Plan). Appendix B contains a more detailed list of the actions addressed in this table. The more significant actions for water temperature are described in more detail below.

RPA action 141 evaluated the link between high water temperatures and associated disease on juvenile migration patterns during critical periods in the lower Snake and lower Columbia Rivers. Under this action several agencies collected hydrodynamic and water quality data during 2001 and 2002 for the lower Snake. The USACE assembled the 2002 data into a database. Several agencies also monitored summer migrants, the susceptibility of these fish to disease, and the link between temperature and migrant mortality. In coordination with RPA 143, these data were combined with GIS and numerical modeling efforts (e.g., RPA 143) to help evaluate long-term survival in relation to water temperature.

RPA action 143 called for the Action Agencies to coordinate with NOAA Fisheries, EPA, states, and tribes to develop a plan to collect data and model water temperature effects of alternative Snake River project operations. The geographic scope of RPA action was the Snake River Basin from Dworshak Dam on the North Fork Clearwater River and Hells Canyon Dam on the Snake River to the confluence of the Snake River at the Columbia River.

A Water Temperature Modeling and Data Collection Plan for the Lower Snake River Basin was prepared in October 9, 2003. The RPA Action 143 Technical Team which prepared the Plan recommended to the regional forum WQT that the CE-QUAL-W2 model be adopted for development in the river reaches of interest and identified a data collection strategy. The team proposed to build an initial model domain for the minimum area needed for effective evaluation of operational effects on temperature (Phase 1) and expand the model in subsequent phases. The proposed phases were as follows:

Table 13 Model development for 2000 BiOp RPA Action 143.

Phase	North Fork Clearwater Boundary	Mainstem Clearwater Boundary	Upstream Snake River Boundary	Downstream Snake River Boundary
1	Mouth	Orofino	Anatone (RM 169)	Lower Granite Dam
2	Dworshak Reservoir Head	Orofino	Hells Canyon Dam Tailrace	Mouth
3	Dworshak Reservoir Head	Orofino	Brownlee Reservoir Head	Mouth

The Corps and BPA were responsible for implementing the model and data collection efforts. The inter-agency technical team participating in this plan development was asked to continue in a technical review role. They reviewed potential contractor Scopes of Work, field data collection and analysis, assisted in defining the period of record for use in model evaluation and review and comment on reports produced during the development. The team, along with the regional forum TMT and WQT, subsequently defined and identified preliminary model runs required to answer questions originally posed by the team.

Progress on these tasks was highly dependent on available funding and has followed the schedule given below.

FY2002-2003 Tasks

- Screen available data
- Initiate new data collection

FY2004 Tasks

- Collect additional field data
- Select periods for model evaluation
- Complete model setup including evaluation
- Technical team review calibration and verification report.

FY2005 Tasks

- System development to operate as real-time tool for use by regional interests
- Expand to Phase 2 Geographic Scope
- Revise Data Collection as needed to support Phase 2 and other model input improvements.

FY2006 Tasks

- Expand to Phase 3 Geographic Scope with Anatone as a hard boundary on the Snake River.
- Revise data collection as needed to support Phase 3 and other model inputs and improvements.

FY2007 and Beyond

- Implementation at Walla Walla District.
- Model optimization

V. CONCLUSIONS

This Water Quality Plan is prepared to describe completed, ongoing, and planned actions by the Corps and other entities to protect fish species and improve water quality in the mainstem Columbia and Snake rivers. The actions described in the Plan are intended to address measures contained in ESA BiOps, help implement TMDLs for TDG, and move toward attainment of WQS for water temperature. These actions work together to meet provisions of both CWA and ESA.

In developing the 2008 BiOp, NOAA Fisheries considered the respective ecological objectives of both the CWA and ESA since listed species benefit from improved water quality. It is recognized that actions to improve water quality may be detrimental to, or have minimal or negligible beneficial effects on listed fish species. Conversely, increased spill to meet ESA objectives may detrimentally affect the ability to attain WQS in a particular reach of the Columbia or Snake rivers, and negatively affect resident fish species. The Plan strives to pursue both CWA and ESA objectives so that adequate fish passage survival is achieved at dams while also improving water quality in the waterbodies in the mainstem Columbia and Snake rivers.

VI. REFERENCES

Anglin, D.R., P.A.Ocker, J.J. Skalicky. 1999. Section E of Ward, David L.- Oregon Dept. of Fish and Wildlife, 1999, Effects of Mitigative Measures on Productivity of White Sturgeon Populations in the Columbia River Downstream from McNary Dam, and Determine the Status and Habitat Requirements of White Sturgeon Populations in the Columbia and Snake Rivers Upstream from McNary Dam, 1997 Annual Report to Bonneville Power Administration.

Benner, P. A., and J. R. Sedell. 1997. Upper Willamette River landscape: a historic perspective. Pages 23-47 *in* A. Laenen and D. Dunnette, editors. River quality: dynamics and restoration. CRC Lewis Publishers, Boca Raton, Florida.

Bennett, D. H., M. H. Karr, and M. M. Madsen. 1997a. Thermal and velocity characteristics in the Lower Snake River reservoirs, Washington, as a result of regulated upstream water releases. University of Idaho and Columbia River Intertribal Fish Commission, prepared for U. S. Army Corps of Engineers, Walla Walla District, Walla Walla, Washington.

Carroll, J.H. 2004. Total Dissolved Gas forebay Fixed Monitoring Station review and evaluation for Lower Snake River projects and McNary Dam, 2003-2004. OA Systems Corporation for U.S. Army Corps of Engineers, Walla Walla District, Walla Walla, Washington.

Caudill, C.C., T.S. Clabough, G.P. Naughton, and C.A. Peery. 2006. Water temperatures in adult fishways at mainstem dams on the Snake and Columbia Rivers: Phase 2 – Biological Effects. Technical Report 2006-3. University of Idaho and NOAA-Fisheries, prepared for U.S. Army Corps of Engineers, Walla Walla District, Walla Walla, Washington.

Columbia River Data Access in Real Time (DART). 2003. Columbia Basin Research, School of Aquatic & Fishery Sciences, Univ of Washington. http://www.cbr.washington.edu/dart/dart.html.

Coutant, C. C. 1999. Perspectives on temperature in the Pacific Northwest's fresh waters. Oak Ridge National Laboratory, Environmental Sciences Division, Publication 4849, Oak Ridge, Tennessee.

Dalen, J., M. Jonas and R. Stansell. 1999. Adult fishway water temperatures at Bonneville, The Dalles and John Day dams, 1994-1998. Fish Field Unit, North Pacific Division, Portland District, U.S. Army Corps of Engineers.

Davidson, F.A. 1969. Columbia River Temperature at Rock Island Dam From 1913 to 1968. Public Utility District of Grant County, Ephrata, Washington.

Eldridge, E. F. 1963. Proceedings of the twelfth Pacific Northwest Symposium on water pollution research: Water temperature, influences, effects, and control. U.S. Department of Health, Education, and Welfare, Public Health Service, Pacific Northwest Water Laboratory, Corvallis, Oregon, November 7, 1963.

Environmental Protection Agency. 1971. Columbia River Thermal Effects Study, Volume 2. Temperature Prediction.

Frizell, K.H. and Vermeyen, T.B. 1997. Investigative trip to Grand Coulee Dam prior to performing total dissolved gas tests in the river. U.S. Bureau of Reclamation, TR-97-16.

Geist, David R., Timothy P. Hanrahan, Evan V. Arntzen, Geoffrey A. McMichael, Christopher J. Murray, and Yi-Ju Chien - Pacific Northwest National Laboratory, Physicochemical characteristics of the hyporheic zone affect redd site selection of chum and fall Chinook salmon, Columbia River, 2001, Report to Bonneville Power Administration, Contract No. 00000652, Project No. 199900304, 26 electronic pages (BPA Report DOE/BP-00000652-5)

Goldschmid. R. M. 2001. Treaty Implications of Dissolved Gas Management in the Columbia River Basin for The British Columbia Ministry of Water, Land and Air Protection and The Columbia River Transboundary Gas Group.

Healey, M. C. 1991. Life history of Chinook salmon (*Oncorhynchus tshawytscha*). Pages 312 to 393, *in* C. Groot and L.Margolis, editors, Pacific salmon life histories. UBC press, Vancouver, British Columbia.

Idaho Department of Environmental Quality (IDEQ) and Oregon Department of Environmental Quality (ODEQ). 2004. Snake River-Hells Canyon total maximum daily load (TMDL). IDEQ, Boise Regional Office, Boise, ID, and ODEQ, Pendleton Office, Pendleton, OR. 710 p. plus appendices.

Idaho Department of Environmental Quality and Oregon Department of Environmental Quality. Dec 2001. Snake River Hells Canyon - Total Maximum Daily Load. Draft

Idaho Power Company (IPC). 2003. New license application: Hells Canyon Hydroelectric Project. IPC, Boise, ID. 6 CD set. Submitted to the Federal Energy Regulatory Commission. Available at: www.idahopower.com/riversrec/relicensing/hellscanyon/application.htm.

Idaho Power Company (IPC). 2005. Response to FERC additional information request WQ-2(a). Conceptual design report. Temperature Control. Additional information request WQ-2 for new license application: Hells Canyon Hydroelectric Complex. Idaho Power Company, Boise, ID. 233 p.

Idaho Power Company (IPC). 2005a. Response to FERC additional information request WQ-2(b). Preliminary screening of alternative designs to meet temperature objectives. Draft report. Additional information request WQ-2 for new license application: Hells Canyon Hydroelectric Complex. Idaho Power Company, Boise, ID. 65 p.

Idaho Power Company (IPC). 2005b. Response to FERC additional information request WQ-2(c). Detailed evaluation of alternative temperature control structures. Final report. Additional information request WQ-2 for new license application: Hells Canyon Hydroelectric Complex. Idaho Power Company, Boise, ID. 192 p.

Idaho Power Company (IPC). 2005c. Response to FERC comments on WQ-2(c). Final report. Additional information request WQ-2 for new license application: Hells Canyon Hydroelectric Complex. Idaho Power Company, Boise, ID. 12 p.

Idaho Power Company (IPC). 2008. Section 401 Water Quality Certification Application. Hells Canyon Complex. Submitted August 8, 2008. 188 p. plus Exhibits. Available on the Web: http://www.idahopower.com/riversrec/relicensing/hellscanyon/application.htm

Independent Science Group. 2000. Return to the River. Northwest Power Planning Council, Document #2000-12.

Johnson, E., et al. 2005. Hydrostatic compensation benefits of adult Chinook salmon and steelhead migrating through the Columbia - Snake Hydrosystem, 2002. Final Idaho Fish and Wildlife cooperative Unit Technical Report, 2005. Available world wide web: http://www.cnr.uidaho.edu/uiferl/pdf%20reports/02%20TDG%20Report.pdf

Keefer, M.L., C.A. Peery, and B. Burke. 2003. Passage of radio-tagged adult salmon and steelhead at John Day Dam with emphasis on fishway temperatures: 1997-1998. Technical Report 2003-1. Idaho Cooperative Fish and Wildlife Research Unit. U.S. Army Corps of Engineers, Portland District, Portland, OR.

Ligon, F. K., W. E. Dietrich, and W. J. Trush. 1995. Downstream ecological effects of dams: a geomorphic perspective. Bioscience 45:183-192.

Major, R.L. and J.L. Mighell. 1966. Influence of Rocky Reach Dam and the Temperature of the Okanagan River on the upstream migration of sockeye salmon. Fishery Bulletin 66(1): 131-147. U.S. Dept. of Commerce, NOAA - NMFS Scientific Publications Office.

McGrath, K.E., E.M. Dawley, and D.R. Geist. 2006. Total dissolved gas effects on fishes of the lower Columbia River. Report # PNNL-15525. Pacific Northwest National Laboratory, Richland, WA. 19 pp. + appendix.

Myers, R., J. Harrison, S. K. Parkinson, B. Hoelscher, J. Naymik, and S. E. Parkinson. 2003. Pollutant transport and processing in the Hells Canyon Complex. Final report. In: Technical appendices for new license application: Hells Canyon Hydroelectric Complex. Idaho Power Company, Boise, ID. Technical Report E.2.2-2. 201 p.

Myers, R., and S.E. Parkinson. 2003. Hells Canyon Complex total dissolved gas study. Revised version. In: Technical appendices for new license application: Hells Canyon Hydroelectric Complex. Idaho Power Company, Boise, ID. Technical Report E.2.2-4. 36 p. plus appendix.

National Marine Fisheries Service (NMFS) 2000 Biological Opinion (BiOp) on the operation of the Federal Columbia River Power System (FCRPS)

NMFS. 2000. White paper: salmonid travel time and survival related to flow in the Columbia River Basin. NMFS NWFSC, Seattle, WA

NOAA Fisheries. 2004. Biological Opinion: Consultation on Remand for Operation of the Columbia River Power System and 19 Bureau of Reclamation Projects in the Columbia Basin, November 30, 2004. NOAA Fisheries, Northwest Region, Seattle, Washington. NOAA Fisheries Log Number: F/NWR/2004/00727.

Neitzel, D. A., et al. 2004. Prevention of prespawning mortality: Cause of salmon headburn and cranial lesions. Final Report to USACE, Portland District, Contract DE-AC06-7GRL01830, PNNL, June 2004.

Patankar, S.V. (1980) Numerical Heat Transfer and Fluid Flow Computational Methods in Mechanics and Thermal Science Hemisphere Publishing

Peery, C. A. and T. C. Bjornn. 2002. Water temperatures and passage of adult salmon and steelhead in the Lower Snake River. US Geological Survey, Idaho Cooperative Fish and Wildlife Research Unit. University of Idaho, Moscow, ID 83844-1141. Draft Technical Report 02-1 to U. S. Army Corps of Engineers, Walla Walla District.

Petersen, J.H. and J.F. Kitchell. 2001. Climate regimes and water temperature changes in the Columbia River: bioenergetic implications for predators of juvenile salmon. Can. J. Fish. Aquat. Sci. 58: 1831-1841.

Pickett, P.J. and R. Harding. Sept 2002. Total Maximum Daily Load For Lower Columbia River Total Dissolved Gas. Washington State Department of Ecology and Oregon Department of Environmental Quality and Washington State Department of Ecology Publication No. 02-03-004

Poole, G. C., and C. H. Berman. 2001. An ecological perspective on in-stream temperature: natural heat dynamics and mechanisms of human-caused thermal degradation. Environmental Management 27(6):787-802.

Richter, T. J., J. Naymik, and J. A. Chandler. 2006. HCC Gas Bubble Trauma Monitoring Study. Exhibit 6.3-1 *In* Section 401 Water Quality Certification Application. Hells Canyon Complex. Submitted August 8, 2008. Available at: <http://www.idahopower.com/riversrec/relicensing/hellscanyon/application.htm>.

Schneider, M.L. and Carroll, J.C. 1999. TDG exchange during spillway releases at Chief Joseph Dam, near-field study, June 6-10, 1999. U.S. Army Waterways Experiment Station.

Schneider, M.L. 1999. Total dissolved gas exchange at Grand Coulee Dam, draft memorandum for record. U.S. Army Engineer Research and Development Center, Vicksburg, MS.

Schneider, M.L. 2003. Joint operation of Chief Joseph and Grand Coulee Dams for power and total dissolved gas production, draft memorandum for record. U.S. Army Engineer Research and Development Center, Vicksburg, MS.

Schneider, M.L., S. C. Wilhelms, and L.I. Yates. 2006. Draft Total Dissolved Gas exchange at Lower Monumental Dam, 2004 spill season. U.S. Army Corps of Engineers, Engineer Research and Development Center, Dallesport, Washington.

Sylvester, R. O. 1958. Water quality studies in the Columbia River basin. U.S. Fish and Wildlife Service, Special Scientific Report-Fisheries No. 239.

Tiffan, Kenneth F. Dennis W. Rondorf - U.S. Geological Survey, William P. Connor, Howard L. Burge - U.S. Fish and Wildlife Service, Post-Release Attributes And Survival Of Hatchery And Natural Fall Chinook Salmon In The Snake River Annual Report 1999, Report to Bonneville Power Administration, Contract No. 00000161- , Project No. 199102900, 140 pp. (BPA Report DOE/BP-00000161-1)

U.S. Army Corps of Engineers (USACE). 1993. 1992 Reservoir Drawdown Test – Lower Granite and Little Goose Dams. USACE Walla Walla District.

USACE. 1999. Corps Digest of Water Resources Policies and Authorities, Engineering Pamphlet 1165-2-1, July 31, 1999.

USACE. 2002a. Lower Snake River Juvenile Salmon Migration Feasibility Study Final Report. USACE Walla Walla District.

USACE. 2002b. John Day Drawdown Test. Phase I. USACE Portland District.

USACE. 2002c. Corps of Engineers Dissolved Gas and Water Temperature Monitoring, Columbia River Basin. USACE Northwestern Division, Portland, OR.

USACE. 2002d. Dissolved Gas Abatement Study Final Phase II Report. USACE Walla Walla District.

USACE. 2004. Water temperatures in adult fishways at mainstem dams on the Snake and Columbia Rivers: Phase 1 – Physical Characterization. USACE Walla Walla District.

USACE, Reclamation, and BPA. 2004. Final Updated Proposed Action for the FCRPS Biological Opinion Remand. November 24, 2004.

United States Commission on Fish and Fisheries, 1878. Report of the Commissioner.

U.S. Department of the Interior Fish and Wildlife Service. 1958. Air and Water Temperature Studies for 1957, Middle Snake River Drainage, Idaho-Oregon-Nevada-Washington. Progress Report.

Vermeyen, Tracy B. 2000. Review of past studies and data related to temperature management options for the Columbia River below Grand Coulee Dam, Washington. Bureau of Reclamation, Water Resources Laboratory, Technical Services Center, Denver CO.

Watson, D.G. 1970. Fall Chinook salmon spawning in the Hanford Reach 1947-1969. Battelle Memorial Institute, Pacific Northwest National Laboratory, Richland, WA.

APPENDIX A – TDG MATRICES

The following tables represent the recent and future efforts of the Corps and other agencies to address TDG issues in the Columbia River basin (LC = Lower Columbia River TMDL; LS = Lower Snake River TMDL; MC = Mid-Columbia TMDL; I = Phase I; II = Phase II; ____ = Completed Action; ____ = Ongoing Action).

Table A-1 Monitoring System Schedule

Action Item #	Type Of Measure	Project Location	TDG Measures	Lead Agency	Status/ Year(s)	TMDL IP Phase	ESA Derived Action
Monitoring 1	Study	FCRPS	Review/Analysis of WQ Monitors	Corps	Dec-02	MC-I	✓
Monitoring 2	Fieldwork	FCRPS	Install Equipment for WQ Monitors	Corps	Mar-03	MC-I	✓
Monitoring 3	Monitoring	FCRPS	Report on WQ Monitors	Corps	Sep-03	MC-I	✓

Table A-2 Overall System

Action Item #	Type Of Measure	Project Location	TDG Measures	Lead Agency	Status/ Year(s)	TMDL IP Phase	ESA Derived Action
Systemwide 1	Study	FCRPS	DGAS	Corps	1994-2002		✓
Systemwide 2	Activity	FCRPS	Predator Removal/Abatement	BPA	Ongoing	LC-II LS-II	✓
Systemwide 3	Operations	FCRPS	Improved O&M	Corps	Ongoing	LC-II LS-II	✓
Systemwide 4	Studies	FCRPS	Turbine Survival Program	Corps	Phase I – 2003 Phase II - 2004	LC-II LS-II	✓
Systemwide 5	Model	FCRPS	SYSTDG	Corps	2000		✓

Table A-3 Federal Mid-Columbia River

Action Item #	Type Of Measure	Project Location	TDG Measures	Lead Agency	Status/ Year(s)	TMDL IP Phase	ESA Derived Action
Fed Mid-C - 1	Operational	Grand Coulee	Shift spill to Chief Joseph Dam	Corps	2004	MC-I	✓
Fed Mid-C - 2	Physical	Grand Coulee	Submerge spill by extending outlet tubes	BoR	?	MC-I	
Fed Mid-C - 3	Studies	Chief Joseph	Physical Model Built	Corps	1999	MC-I	✓
Fed Mid-C - 4	Studies	Chief Joseph	Flow Deflector Models Tested	Corps	2000	MC-I	✓
Fed Mid-C - 5	Operational	Chief Joseph	Shift power generation to Grand Coulee Dam	Corps	2004	MC-I	✓
Fed Mid-C - 6	Physical	Chief Joseph	Flow Deflectors	Corps	Completed 2008	LC-I MC-I	✓

Table A-4 Hells Canyon

Action Item #	Type Of Measure	Project Location	TDG Measures	Lead Agency	Status/ Year(s)	TMDL IP Phase	ESA Derived Action
Hells-C - 1	Study	Brownlee	TDG Monitoring	IPC	1997, 1998,		
Hells-C - 2	Study	Oxbow	TDG Monitoring	IPC	1997, 1998,		
Hells-C - 3	Study	Hells Canyon	TDG Monitoring	IPC	1997, 1998, 1999,		
Hells-C - 4	Study	Hells Canyon	Flow Deflectors	IPC	2000		
Hells-C - 5	Study	Brownlee	Flow Deflectors	IPC	2005		
Hells-C – 6	Study	Brownlee Oxbow, Hell Canyon	TDG and GBT Monitoring	IPC	2006		
Hells-C – 7	Study	Oxbow	Flow Deflectors	IPC	2007		

Table A-5 Lower Snake River History and Schedule

Action Item #	Type Of Measure	Project Location	TDG Measures	Lead Agency	Status/ Year(s)	TMDL IP Phase	ESA Derived Action
Lower Snake 1	Bio Study Physical – Operational	Lower Granite	Surface Bypass Collection	Corps	1995 – 2000		✓
Lower Snake 2	Study	Lower Granite	Sectional Hydraulic Model	Corps	TBD		✓
Lower Snake 3	Physical	Lower Granite	Optimize Deflectors	Corps	TBD		✓
Lower Snake 4	Study	Lower Granite	Spill Patterns	Corps	Ongoing	LC-II LS-II	✓
Lower Snake 5	Physical	Lower Granite	Pier Nose Extensions	Corps	TBD		✓
Lower Snake 6	Physical	Lower Granite	Divider Walls	Corps	TBD	LC-I LS-I	✓
Lower Snake 7	Physical – Bio Study	Lower Granite	RSW	Corps	2002 – 2007	LC-I LS-I	✓
Lower Snake 8	Bio Study	Lower Granite	Spillway Passage Survival Study	Corps	2003 – 2006	LC-I LS-I	✓
Lower Snake 9	Study	Little Goose	General Model Tests	Corps	2007-2008		✓
Lower Snake 10	Operational	Little Goose	Spill Patterns	Corps	Final Patterns TBD after TSW installation.	LC-II LS-II	✓

Table A-5 Lower Snake River History and Schedule (Continued)

Action Item #	Type Of Measure	Project Location	TDG Measures	Lead Agency	Status/ Year(s)	TMDL IP Phase	ESA Derived Action
Lower Snake 11	Study – Physical - Operational	Little Goose	End Bay Deflectors	Corps	2009	LC-I LS-I	✓
Lower Snake 12	Study – Physical - Operational	Little Goose	Optimize Deflectors	Corps	TBD		✓
Lower Snake 13	Study – Physical - Operational	Little Goose	Spillway Divider Wall	Corps	TBD	LC-I LS-I	✓
Lower Snake 14	Study – Physical - Operational	Little Goose	Spillway Sectional Model Test	Corps	2008		✓
Lower Snake 15	Bio Study	Little Goose	Spill Passage Survival Studies	Corps	2004 – 2009	LC-I LS-I	✓
Lower Snake 16	Gas Test	Little Goose	Near Field Test	Corps	TBD		✓
Lower Snake 17	Physical – Bio Study	Little Goose	TSW	Corps	2009 – 2011 TSW currently under construction with in service date of March 2009	LC-II LS-II	✓
Lower Snake 18	Study	Lower Monumental	Physical Model Development	Corps	1999		✓
Lower Snake 19	Physical	Lower Monumental	End Bay deflectors	Corps	2001 – 2003	LC-I LS-1	✓
Lower Snake 20	Operational	Lower Monumental	Spill patterns	Corps	Ongoing.	LC-II LS-II	✓
Lower Snake 21	Physical	Lower Monumental	Divider Wall Report	Corps	2004	LC-I LS-I	✓
Lower Snake 22	Physical	Lower Monumental	Report on Juvenile Bypass Outfall Reloc.	Corps	2004	LC-I LS-I	✓
Lower Snake 23	Physical	Lower Monumental	Stilling Basin Repair	Corps	2001 – 2003		✓

Table A-5 Lower Snake River History and Schedule (Continued)

Action Item #	Type Of Measure	Project Location	TDG Measures	Lead Agency	Status/ Year(s)	TMDL IP Phase	ESA Derived Action
Lower Snake 24	Bio Study	Lower Monumental	Passage/Survival	Corps	Ongoing	LC-I LS-I	✓
Lower Snake 25	Study	Lower Monumental	Extended Fish Screens	Corps	TBD	LC-II LS-II	✓
Lower Snake 26	Physical – Bio Study	Lower Monumental	RSW	Corps	2008 – 2010 RSW placed in service March 2008	LC-II LS-II	✓
Lower Snake 27	Physical	Ice Harbor	Flow Deflectors (4 deflectors)	Corps	1996	LC-I LS-I	✓
Lower Snake 28	Physical	Ice Harbor	Flow Deflectors (4 deflectors)	Corps	1997	LC-I LS-I	✓
Lower Snake 29	Physical	Ice Harbor	Flow Deflectors (2 deflectors)	Corps	1999	LC-I LS-I	✓
Lower Snake 30	Operational	Ice Harbor	Spill Patterns	Corps	1999 – 2006 Final Patterns TBD in conjunction with RSW operations	LC-II LS-II	✓
Lower Snake 31	Bio Study	Ice Harbor	Passage/Survival	Corps	1999 – 2005	LC-I LS-I	✓
Lower Snake 32	Physical – Bio Study – Operation	Ice Harbor	RSW	Corps	2003 – 2008	LC-II LS-II	✓
Lower Snake 33	Phys. – Study	Ice Harbor	Divider Wall	Corps	TBD	LC-I	✓

Table A-6 Clearwater River

Action Item #	Type Of Measure	Project Location	TDG Measures	Lead Agency	Status/ Year(s)	TMDL IP Phase	ESA Derived Action
Clearwater 1	Study	Dworshak	Identify potential methods of reducing production of TDG.	Corps	TBD – Not Currently Funded		
Clearwater 2	Physical	Dworshak	Modifications as recommended by TDG study. Modifications may include spillway modifications, Turbine Installation etc.	Corps	TBD Based on Clearwater 1		
Clearwater 3	Physical	Dworshak	Spillway Modifications	Corps	TBD		
Clearwater 4	Physical	Dworshak	Turbine Installation	Corps	TBD		
Clearwater 5	Study	Dworshak	Hydrologic Analysis	Corps	TBD		
Clearwater 6	Study	Dworshak	Model Construction	Corps	TBD		

Table A-7 Lower Columbia River

Action Item #	Type Of Measure	Project Location	TDG Measures	Lead Agency	Status/ Year(s)	TMDL IP Phase	ESA Derived Action
L Columbia 1	Document	System	Final TMDL-TDG	Corps	2002		✓
L Columbia 2	Physical – Operational – Study	McNary	Gate Hoists	Corps	2008		✓
L Columbia 3	Physical – Operational – Study	McNary	Deflector Optimization	Corps	2002		✓
L Columbia 4	Physical – Operational – Study	McNary	Spill Patterns	Corps	2002	LC-II	✓

Table A-7 Lower Columbia River (Continued)

Action Item #	Type Of Measure	Project Location	TDG Measures	Lead Agency	Status/ Year(s)	TMDL IP Phase	ESA Derived Action
L Columbia 5	Physical – Operational – Study	McNary	Divider Walls	Corps	TBD	LC-I	✓
L Columbia 6	Physical – Operational – Study	McNary	Training Walls	Corps	TBD		✓
L Columbia 7	Physical – Operational – Study	McNary	Modeling	Corps	2005		✓
L Columbia 8	Physical – Operational – Study	McNary	Outfall relocation	Corps	2009-2011	II	✓
L Columbia 9	Physical – Bio Study	McNary	RSW/TSW or other Surface Passage Measures	Corps	2007 - TBD		✓
L Columbia 10	Physical	McNary	Turbine Replacement	Corps	Deferred - TBD	LC-II	✓
L Columbia 11	Bio Study	McNary	Spillway Passage Survival	Corps	–Ongoing	LC-I LC-II	✓
L Columbia 12	Study	McNary	Near Field Test	Corps	Not Scheduled		✓
L Columbia 13	Physical	McNary	Endbay Deflectors	Corps	2002	LC-I	✓
L Columbia 14	Physical	John Day	Flow Deflectors (18/20)	Corps	1998 – 1999	LC-I	✓
L Columbia 15	Study - Physical	John Day	Surface Bypass Spillway Weirs Testing	Corps	2008-2009	LC-II	✓
L Columbia 16	Study-Physical	John Day	Tailrace Passage/Survival Improvement Studies	Corps	Ongoing	LC-I - II	✓

Table A-7 Lower Columbia River (Continued)

Action Item #	Type Of Measure	Project Location	TDG Measures	Lead Agency	Status/ Year(s)	TMDL IP Phase	ESA Derived Action
L Columbia 17	Physical	John Day	End Bay Deflectors	Corps	TBD	LC-I	✓
L Columbia 18	Physical	John Day	End Bay Deflector – Bay 1	Corps	TBD	LC-I	✓
L Columbia 19	Study – Physical	The Dalles	Spillway Improvement Study	Corps	Ongoing	LC-I	✓
L Columbia 20	Study – Physical	The Dalles	Spill Wall bays 6-7	Corps	2004	LC-I	✓
L Columbia 21	Study – Physical	The Dalles	Forebay Guidance	Corps	TBD		✓
L Columbia 22	Study – Physical	The Dalles	Spill Wall Bays 8-9	Corps	2010	LC-I	✓
L Columbia 23	Study -Physical –	The Dalles	Surface Bypass	Corps	Deferred		✓
L Columbia 24	Study – Physical	The Dalles	Turbine Intake Blocks	Corps	Terminated	LC-I	✓
L Columbia 25	Study – Physical	The Dalles	Sluiceway Outfall relocation	Corps	TBD	LC-I	✓
L Columbia 26	Bio Study	The Dalles	Spillway Survival Study	Corps	2010 – 2011	LC-I - II	✓
L Columbia 27	Physical	Bonneville	Spillway Deflectors (13/18)	Corps	1970's	LC-I	✓
L Columbia 28	Physical	Bonneville	Spillway Deflectors (18/18)	Corps	2002	LC-I	✓
L Columbia 29	Study - Physical	Bonneville	Spillway Modifications	Corps	Ongoing	I	✓

Table A-7 Lower Columbia River (Continued)

Action Item #	Type Of Measure	Project Location	TDG Measures	Lead Agency	Status/ Year(s)	TMDL IP Phase	ESA Derived Action
L Columbia 30	Study – Physical	Bonneville	PH1 Surface Bypass Sluiceway Modifications	Corps	2009-2010	LC-I	✓
L Columbia 31	Physical	Bonneville	PH2 Corner Collector	Corps	2004	LC-I	✓
L Columbia 32	Physical Study	Bonneville	Turbine Improvements (MGRs)	Corps	2010	LC-II	✓
L Columbia 33	Physical	Bonneville	PH2 FGE Improvement	Corps	2008	LC-I	✓
L Columbia 34	Bio Study	Bonneville	Passage/Survival Studies	Corps	2009-2010	LC-I - II	✓
L Columbia 35	Study	Bonneville	Near Field Testing	Corps	2002		✓
L Columbia 36	Physical	Bonneville	Improve Existing Deflectors if needed	Corps	Ongoing		✓
L Columbia 37	Operational	Bonneville	Spill Patterns	Corps	Ongoing		✓
L Columbia 38	Physical – Bio Study	Bonneville	Behavioral Guidance System Installation	Corps	Completed Install 08, Bio-Studies Ongoing		✓
L Columbia 39	Study	Bonneville	Bon Dam Spillway and Stilling Basin Alternatives Report	Corps	2009-2010		✓

The following tables represent the recent and future efforts of the Corps and other agencies to address TDG issues in the Columbia River basin.

APPENDIX B – CLEAN WATER ACT/ESA

List of CWA and ESA actions in the 2000 NMFS FCRPS BiOp, Appendix B, that are also called for in that BiOp's RPA.

FCRPS Project	**Description of Action**	**Action Type**	**In Biological Opinion Section**
	Dissolved Gas Actions		
Systemwide	Development of water quality plan	Plan	9.4.2.4**,** RPA 5
Lower Granite	Gas fast-track; spillway deflector optimization evaluation	Study	9.6.1.7.2, RPA 134
Little Goose	Gas fast-track; spillway deflector optimization evaluation	Study	9.6.1.7.2, RPA 134
Lower Monumental	Gas fast-track; spillway deflector optimization evaluation; fish passage efficiency and survival	Studies	9.6.1.7.2, RPA 134
Ice Harbor	Post-installation spillway deflector evaluations; fish passage efficiency and survival	Studies	9.6.1.7.2, RPA 134
McNary	Gas fast-track; spillway deflector optimization evaluation; fish passage efficiency and survival	Studies	9.6.1.7.2, RPA 134
John Day	Post-installation spillway deflector evaluations, gas fast-track and fish passage efficiency	Studies	9.6.1.7.2, RPA 134
John Day*	Design and implement spillway end deflector	Design and implementation	9.6.1.7.2, RPA 140
The Dalles	Spill and fish passage survival evaluation; gas fast-track	Studies	9.6.1.7.2, RPA 134
Bonneville	Design/implement gas fast-track and additional spillway deflectors; fish passage efficiency	Implementation and studies	9.6.1.7.2, RPA 134
Systemwide	Complete system gas abatement study	Study	9.6.1.7.2, RPA 130
Chief Joseph	Gas fast-track; spillway deflector design and installation	Implementation	9.6.1.7.2, RPA 136
Grand Coulee	Gas abatement study; evaluate GCL-CHJ gas abatement options	Study	9.6.1.7.2, RPA 136
Libby	Evaluate gas abatement alternatives	Study	9.6.1.7.2, RPA 137
Dworshak	Evaluate gas abatement alternatives	Study	9.6.1.7.2, RPA 139
Systemwide	Total dissolved gas monitoring program	Monitoring	9.6.1.7.2, RPA 131
Systemwide*	Evaluate fixed forebay TDG monitors to determine best location	Study and implementation	9.6.1.7.2, RPA 132
Systemwide	Develop system dissolved gas model	Modeling; study	9.6.1.7.2, RPA 133
Systemwide*	Evaluate gas entrainment divider walls at FCRPS mainstem projects	Study	9.6.1.7.2, RPA 135
Lower Granite	Prototype surface spillway bypass	Construct prototype & study	9.6.1.4.5, 9.67.1.7.2, RPA 80, RPA138
John Day	Prototype surface spillway bypass	Construct prototype & study	9.6.1.4.5, 9.6.1.7.2, RPA 72, RPA 138

Ice Harbor	Prototype surface spillway bypass	Construct prototype & study	9.6.1.4.5, 9.6.1.7.2, RPA 72, RPA 138

* Action not contained in Appendix B but called for in Sec. 9 of NMFS Biological Opinion.

List of CWA and ESA actions in the 2000 NMFS FCRPS BiOp, Appendix B, that are also called for in that BiOp's RPA. (continued)

FCRPS Project	Description of Action	Action Type	In Biological Opinion Section
	Water Temperature Actions		
Systemwide	Development of water quality plan	Plan	9.4.2.4, RPA 5
Systemwide	Water temperature data collection/monitoring program	Monitoring	9.6.1.7.2, RPA 143
Systemwide	Develop plan to model system water temperature and operations	Modeling; study	9.6.1.7.2, RPA 143
Systemwide	Evaluate fish ladder water temps.	Study	9.6.1.6.2, RPA 114
Systemwide	Evaluate temp effects on juvenile passage behavior and survival	Study	9.6.1.7.2, RPA 141
Unspecified dam	Conduct comprehensive depth and temp investigation to identify adult passage losses	Study	9.6.1.6.2, RPA 115
Dworshak	DWR NFH water supply improvements to allow temp oper.	Implementation	9.6.1.2.6, RPA 33
Dworshak and L. Snake River dams	Water temp control operations; evaluate effects on juvenile and adult passage behavior and pre-spawning mortality	Operations and studies	9.6.1.2.3, RPA 19 9.6.1.6.2, RPA 115, 118, 141
McNary	Monitor/eval temp in juvenile fish bypass facilities & effects on fish	Monitor and study	9.6.1.7.2, RPA 142
	Tributary Actions		
Systemwide	Coordinate with tributary TMDLs and fund ESA-related TMDL implementation	Study and monitoring; plan implementation	9.6.2.1, RPA 152, RPA 154
Columbia Basin Project	Wasteway water quality monitoring and remediation plan	Study and monitoring; plan implementation	9.6.1.2.7, RPA 39
Systemwide	BOR and BPA initiate passage, screening and flow actions in priority subbasins		RPA 149
Systemwide	BPA fund protection of non-federal habitat		RPA 150
Systemwide	BPA establish water brokerage		RPA 151
Systemwide	BPA work with Conservation reserve Enhancement Program and others to establish 100 miles of riparian buffers a year		RPA 153
	Mainstem Habitat		
Systemwide	BPA with EPA and others establish a mainstem habitat research program		RPA 155
	Estuary Actions w/LCREP		
Estuary	Monitoring		RPA 161
Estuary	Wetland Restoration		RPA 160
Estuary	Habitat Needs of Salmon		RPA 159
Estuary	Estuarine Habitat Inventory and Criteria		RPA 158

List of Clean Water Act Actions in Appendix B that are not called for in the 2000 FCRPS Biological Opinion RPA.

FCRPS Project	Description of Action	Action Type	In Biological Opinion Section
Systemwide	Development of Columbia/Snake River TMDLs for dissolved gas and temperature	Study/process	Conservation recommendation 11.8
Grand Coulee	Long-term gas abatement alternative selection study	Study	Conservation recommendation 11.9
Lower Granite	Long-term gas abatement alternative selection study; side channel spillway or raised stilling basin	Study	Conservation recommendation 11.9
Little Goose	Long-term gas abatement alternative selection study; side channel spillway or raised stilling basin	Study	Conservation recommendation 11.9
Lower Monumental	Long-term gas abatement alternative selection study; side channel spillway or raised stilling basin	Study	Conservation recommendation 11.9
Ice Harbor	Long-term gas abatement alternative selection study; side channel spillway or raised stilling basin	Study	Conservation recommendation 11.9
McNary	Long-term gas abatement alternative selection study; side channel spillway or raised stilling basin	Study	Conservation recommendation 11.9
Bonneville	Long-term gas abatement alternative selection study; baffled spillway	Study	Conservation recommendation 11.9
Systemwide	Provide funding to develop tributary TMDLs	Funding	Conservation recommendation 11.11

APPENDIX C – 2009 MONITORING PLAN

The Corps' draft Plan of Action for Dissolved Gas Monitoring in 2009 is available on the web at:

http://www.nwd-wc.usace.army.mil/tmt/wq/tdg_monitoring/2009_draft.pdf

APPENDIX D – WATER TEMPERATURE MATRIX

This appendix is a matrix of all suggestions received, as discussed in section 7 of this water temperature document.

Action Item #	Mainstem Cooling Water Temperature Measures	Anticipated Effect on Temperature and other Benefits to Salmon Recovery	Major Issues or Concerns	Lead Agency	Feasibility of Implementation (Who) -why	Appropriate Next Step	Tests/Studies Required to Implement	Status/ Year(s)	NMFS 2000 FCRPS RPA
M-1	Operate Dworshak Reservoir to Release cool water in July and August to Aid juvenile migration and reduce mainstem Snake River Water Temperatures	Reduction of Water Temperature in the Mainstem Snake and Clearwater Rivers During July and August	- Possible Negative Impact on Growth of Juvenile Fall Chinook - Balancing of Reservoir Elevations vs. Augmentation of flows - Possible Impacts to Adult Salmonid Migration (positive or negative) - TDG Issues with discharge rate - Possible effects to Bull Trout - Further Discussion of effects can be found in the SOR EIS	Corps	Feasible (Corps)	See Action Item 2	None - Implemented Yearly	Tested In 1991, In operation since 1992	19
M-2	Examine the Benefits of Drafting Dworshak an Additional 20 Feet during September to provide cool water to the mainstem	Reduction of Water Temperature in the Mainstem Snake and Clearwater Rivers During September	- Possible Conflict with NMFS 2000 FCRPS BIOP RPA 18 in that Refill Risk to April upper Flood Control Rule Curve is increased. However, NMFS feels there is an acceptable risk of refill to the June 30 full pool. - TDG Issues with discharge rate - The Nez Perce Tribe is concerned with drawdown exposing cultural resources to potential looting or other damage - Idaho does not favor additional impacts to recreation at Dworshak - Further Discussion of drafting Dworshak below 1520 can be found in the SOR EIS	Corps	Feasible (Corps)	Data Analysis and Report of the first year of study (See Action Item 5)	One year of study done, Implementation needs to be studied	A Field Test was Completed in 2002	34
M-3a	Operate the Four Lower Snake River Reservoirs between MOP and MOP+1 from April through roughly October	This is thought to reduce the water surface areas exposed to solar radiation and increase water velocities to limit time exposure to solar radiation	- For 2003, Snake River Dredging Litigation may cause operations of Lower Granite Reservoir to exceed MOP+1 for navigation - Decreased Power Generation and system flexibility - Further discussions of the effects can be found in the SOR EIS	Corps	Feasible (Corps)	None	None - Implemented Yearly	In Progress	20

Action Item #	Mainstem Cooling Water Temperature Measures	Anticipated Effect on Temperature and other Benefits to Salmon Recovery	Major Issues or Concerns	Lead Agency	Feasibility (Who) - why	Appropriate Next Step	Tests/Studies Required to Implement	Status/ Year(s)	NMFS 2000 FCRPS RPA
M-3b	Operate the Four Lower Snake River Reservoirs below MOP, (e.g. at MSL 710 at LGR) or Spillway Crest from April through roughly October	This would further reduce the water surface areas and increase water velocities to limit time exposure to solar radiation	- Temporary draw downs are expected to have continual negative impacts to salmonids - Negative Biological Impacts to Reservoir - Negative Impacts to Navigation/Hydropower/Infrastructure - Negative Impacts to Cultural Res. - Further discussions of the effects can be found in the 1992 Columbia River Salmon Flow Measures Option Analysis/EIS	Corps	Not Feasible (Corps) - fish passage - reservoir ecol. - navigation - hydropower - cultural res.	None	Done	Studied in 1992	-
M-3c	Operate Lower Granite Reservoir at Spillway Crest Year round	This would reduce the water surface areas and increase water velocities to limit time exposure to solar radiation	- Negative Impacts to Cultural Resources - Negative impact to Navigation/Hydropower/Infrastructure	Corps	Not Feasible (Corps) - fish passage - reservoir ecol - navigation - hydropower - cultural res	None	Done	Studied in 1992	-
M-3d	Remove Dams and Reservoirs	This would further reduce the water surface areas exposed to solar radiation and increase water velocities to limit time exposure to solar radiation	- Discussions of the effects can be found in the 2002 Lower Snake River Juvenile Salmon Migration Feasibility Study	Corps	Not Warranted at this Time Under ESA	None Anticipated for CWA	Done	Study Completed in 2002	-
M-3e	Draw down John Day Reservoir to spillway Crest or Natural River	This would reduce the water surface areas and increase water velocities to limit time exposure to solar radiation	- Discussions of the effects can be found in the 2000 John Day Drawdown Study - Cost Prohibitive	Corps	Not recommended (Corps) - Cost - Power - questionable benefits - wildlife	None	Done	Study Completed in 2000	-
M-3f	Drawdown other dams to spillway crest or natural river, temporarily or year round	If Lower Granite and John Day reservoir draw downs are thought to reduce temperature, it is logical to hypothesize that other dams in the Columbia River could be drawn down with similar proposed temperature benefits	-Dams to be considered for drawdown would need to include those in Hells Canyon , Grand Coulee, Canada and PUD dams. -Depending on the operation, drawdown of any reservoir might be expected to have the same impacts as noted in Action item 3b	Unknown	Unknown	Unknown	Unknown	-	-

Action Item #	Mainstem Cooling Water Temperature Measures	Anticipated Effect on Temperature and other Benefits to Salmon Recovery	Impacts or Issues	Lead Agency	Feasibility (Who) -Why	Appropriate Next Step	Tests/Studies Required to Implement	Status/ Year(s)	NMFS 2000 FCRPS RPA
M-4	Grand Coulee Powerhouse Operations	Selective operation of the Left, Right, and Third Powerhouses would be evaluated to determine if there is potential to cool Grand Coulee releases during critical periods.	- Power Constraints may limit benefits – Stratification breaks up in September - Limited duration of downstream cooling effects	BOR	Unknown (BOR)	Decision to Proceed with Study	Modeling of Water Quality Benefits/Estimate Costs	Planning	-
M-5a	Use or Modify Water Intakes at Storage Reservoirs for Selective withdrawal	Selective Withdrawal has been demonstrated at various locations to draw water from a cooler layer in a reservoir and deliver that cooler water downstream	- Except for Grand Coulee (See action Item M-5b) there are no other federal projects that could reduce water temperature in the mainstem Columbia and Snake River. - Currently exists at Dworshak Dam	Corps	Not Feasible at ROR projects (Corps) - No Potential	Action Item M-5b	No Additional Action	None	-
M-5b	Determine feasibility of penstock selective withdrawal at Grand Coulee	Selective Withdrawal has been demonstrated at various locations to draw water from a cooler layer in a reservoir and deliver that cooler water downstream	- Implementation Authority, Possible Resident Fish Constraints in FDR Lake - Possibly Cost Prohibitive	BOR	Unknown (BOR)	Decision to Proceed with Study	Modeling of Water Quality Benefits/Estimate Costs	Planning	-
M-5c	Investigate cool water releases from the Hell's Canyon hydro projects	The Hell's Canyon projects are thought to have some stratification in them during some times of the year, with selective withdrawal, it may be possible to tap a layer of water for downstream cooling effects	- Unknown, however, at a minimum, similar concerns with the Dworshak Reservoir releases - No Authority	Unknown	Unknown (Corps)	TBD	TBD	TBD	-
M-6	Alter the Flood Control Rule Curves	Currently, storage projects are prioritized to fill by June 30 (RPA 18), which maximizes the amount of water to be released in July and august for salmon flows and temperature reduction flows. It is anticipated that any change to release flood control storage would result in more water in the spring since the priority now is refill by the 30th. Therefore, it is anticipated that no additional benefit for reducing mainstem temperatures would occur due to this action.	- TBD, but a t a minimum, augmentation versus reservoir refill, and impacts to the flood plains	Corps	TBD	Federal Appropriation for a Study has been approved	Study Required	TBD	35

Action Item #	Site Specific Water Temperature Measures	Anticipated Effect on Temperature and other Benefits to Salmon Recovery	Major Issues or Concerns	Lead Agency	Feasibility (Who) - Why	Appropriate Next Step	Tests/Studies Required to Implement	Status/ Year(s)	NMFS 2000 FCRPS RPA
M-7	Investigate cool water releases from Canadian hydro projects	US Agencies are not aware of the potential for temperature augmentation associated with releases of water from Canada	- Unknown, however, at a minimum, similar concerns with the Dworshak releases - No Authority	Unknown	Unknown (Corps)	TBD	TBD	TBD	-
M-8	Investigate Banks Lake Selective Withdrawal to draw warm water from Lake Roosevelt	Drawing water from the upper part of the water column into Banks lake may make more, cooler water available in the Mainstem river.	- Implementation Authority -Temp. Constraints in Banks Lake - Possible Resident Fish Constraints in FDR Lake	BOR	Unknown (BOR)	Decision to Proceed with Study	Modeling of Water Quality Benefits/Estimate Costs	Planning	-
M-9	Investigate Groundwater Charging for Cooling Mainstem Water	Charging groundwater in strategic areas may provide areas of upwelling of cooler water from the river bottom, providing cool water refugia and helping to reduce overall river temperature	-Current groundwater contributions -Groundwater contamination -Effectiveness -Appropriate substrate	Unknown	Unknown (Corps)	Unknown	Unknown	-	-

Action Item #	Site Specific Water Temperature Measures	Anticipated Effect on Temperature and other Benefits to Salmon Recovery	Major Issues or Concerns	Lead Agency	Feasibility (Who) - Why	Appropriate Next Step	Tests/Studies Required to Implement	Status/ Year(s)	NMFS 2000 FCRPS RPA
S-1	Modification of Dworshak National Fish Hatchery Water Supply	No change to the reaches affected by the Dworshak Temperature Releases unless cooler water can be released due to modifications at hatchery.	- benefits to the Dworshak hatchery water supply - If cooler water is released, need to consider impacts to juvenile salmon rearing	Corps	Feasible (Corps)	None	Done	In Progress To be Completed in 2003	33
S-2a	Examine the temperatures in the McNary Forebay to determine if there are options to reduce water temperatures in the juvenile bypass systems	Better Understanding of Impacts to Juvenile Salmon Survival related to temperature. Using mixers in the forebay or excavating the shallow water of the forebay on the South Shore may help to disrupt the temperature gradient that occurs there	- Turbine discharge limited -Feasibility of excavation has not yet been evaluated	Corps	Feasible (Corps)	Complete analysis and Report	Field studies completed in 2004-2005	Final Report completed in 2006	142
S-2b	Identify water temperature cooling methods at individual projects for juvenile fish passage	Drawing water through specific turbines has been shown to draw cooler water into juvenile fish facilities at McNary Dam	- If a problem is discovered, implementation of a solution would also need to be studied	Corps	TBD	Complete analysis and Report	Nothing Scheduled	None	141
S-2c	Identify methods to cool river water at individual projects	Selective Operations at various facilities may have potential for cooling the river (See Action 7d)	- If a problem is discovered, implementation of a solution would also need to be studied	Corps	TBD	Complete analysis and Report	Study at Chief Joseph Dam	Completed 2005	-

Action Item #	Research Related Water Temperature Measures	Anticipated Effect on Temperature and other Benefits to Salmon Recovery	Major Issues or Concerns	Lead Agency	Feasibility (Who) -Why	Appropriate Next Step	Tests/Studies Required to Implement	Status/ Year(s)	NMFS 2000 FCRPS RPA
R-1	Conduct Acoustic and Radio Data Storage Tag studies to examine migratory behavior of adults with respect to temperatures and depth. Tracking data should overlay on simulated physical conditions.	Better Understanding of Impacts on Adult Salmon Behavior related to Temperature Releases	- If a problem is discovered, implementation of a solution would also need to be studied - Continued Dworshak Operations	Corps	Feasible (Corps)	Complete Study, Analysis and Report	Study in Progress, 2003 last anticipated year of field study	Ongoing 2000-2003	34, 115
R-2	Conduct studies to examine fish behavior with respect to water temperature in adult fish ladders	Better Understanding of Impacts on Adult Behavior related to temperature	- If a problem is discovered, implementation of a solution would also need to be studied	Corps	Feasible (Corps)	Complete analysis and Report	Study In Progress	In Progress	114
R-3a	Perform additional monitoring of water temperatures in the Snake River and model investigations to evaluate alternative operations of Dworshak	Better Understanding of Impacts of Dworshak Releases	- No Known Negative Impacts – Better understanding of river temperatures	Corps	Feasible (Corps)	Complete analysis and Report	In Progress	In Progress 2002-2008	143
R-3b	Improve water temperature monitoring of the Columbia River System	This action is being performed concurrently with Action Item 8a	- Better understanding of river temperatures	Corps BPA BOR	Feasible (AAs)	Complete analysis and Implement	Study In Progress for TDG	In Progress	-
R-4	Investigate Cool Water Refugia in the Mainstem Rivers	Determine if areas of cool water refugia exist in the mainstem rivers and determine if it is feasible to somehow try to connect these habitats	-Difficult to ascertain -Difficult to quantify	Unknown	Unknown	Unknown	Unknown	-	-
R-5	Perform a "D-Temp" study (Similar to a DGAS Study)	Outline and Define the potential to decrease water temperature in the Columbia River with a modeling study	-Authorization -Funding -Schedule	Unknown	Unknown	Unknown	Unknown	-	-
R-6	Develop a multi-dimensional water quality model for the geographic scope of the water quality plan to determine the effectiveness of water quality measures outlined in Section 7 and other measures as they arise	There currently exists some two and three dimensional models for parts of the Snake and Columbia rivers, further development of models would need to be developed to encompass the geographic scope of the plan.	-Authorization -Funding -Schedule	Multiple but Unknown	Unknown	Unknown	Unknown	-	143 Partial
R-7	Investigate the thermal relationship of temperature on fish diseases.	High water temperatures have been linked to stress and disease in fish. A better base of information to understand the sources of fish disease and mortality at the Columbia Basin dams is needed.	- If a problem is discovered, implementation of a solution would also need to be studied	Corps	Feasible (Corps)	Rework of proposals	Studies anticipated through the AFEP process	Planned for the course of the BiOp	141

APPENDIX E – CORPS PERSPECTIVE

The following information is provided to give the Corps of Engineers perspective on water temperature in the Columbia River Basin. This section may or may not reflect the perspectives of other federal, state, tribal or private agencies. The purpose of this section is to demonstrate that the Snake and Columbia rivers have regularly exhibited periods of high temperatures both pre- and post-impoundment and that there are various causes of increased water temperatures (including the dams).

Data used in this section has been taken from published sources and regional Internet sites. The Corps has not done any detailed analysis or additional research beyond this for this plan, as this was not the purpose of this document. Modeling efforts, much of which has been done by EPA, have been underway for a number of years to evaluate the effects of human activities on river water temperatures. Much of the EPA effort has been performed for various studies and the TMDL process.

Historic water temperatures in the Snake and Columbia rivers are an often-debated topic. Historic measurements in the Columbia and Snake Basins were often done either sporadically, over short periods of time, or with unknown levels of accuracy. Some historic data has been met with skepticism and questions have been raised about the viability of historic data because scientific methods may not have been as rigorous as preferred. The Corps believes that although much of this data may not be suitable for modeling, it should not all be completely rejected.

E-1 Historic Warm Water in the Columbia and Snake Rivers

The mainstem Columbia and Snake rivers have always experienced warm water during specific times of the year, quite often exceeding 20°C. Early ancillary data from the Lower Columbia River downstream of Portland, Oregon can be found in the 1878 Report of the Commissioner, United States Commission on Fish and Fisheries, page 807. In 1875, water temperatures were 20°C or greater for 39 and 31% of the days in July and August respectively (Table 3). While the limited air temperature data for Portland at that time did not indicate that it was an abnormal air temperature year, the precipitation in Portland for July as reported by the National Weather Service was one of the lowest on record (1871-1999 Avg. = 0.63, 1875 = .02).

	% of Days when 12am Temp >= 20C	
	1875	
	July (1-31)	August (2-14)
Columbia River Clifton, Oregon	39%	31%

Table 1. Columbia River midnight single point water temperatures as measured at Clifton, Oregon in 1875.

While this may indicate that this information was not collected in an average year, it can be considered as evidence of historic warm water in the Lower Columbia prior to impoundment.

Additional evidence of warm historic temperatures can be seen in the Bonneville scrollcase data. From 1949-1959, a period when few mainstem dams were in place, temperature records indicate that both maximum and average temperatures regularly exceeded 20°C during August for that period (Figure 1).

Some data was collected in the Snake River prior to the completion of the Hells Canyon Complex, one example was temperature data collected by the USFWS from 1955-1957 (USFWS 1958). They reported that the average daily temperature for July and August in 1957 for sites near Hells Canyon met or exceeded 20°C between 61 and 100% of the time (Table 2).

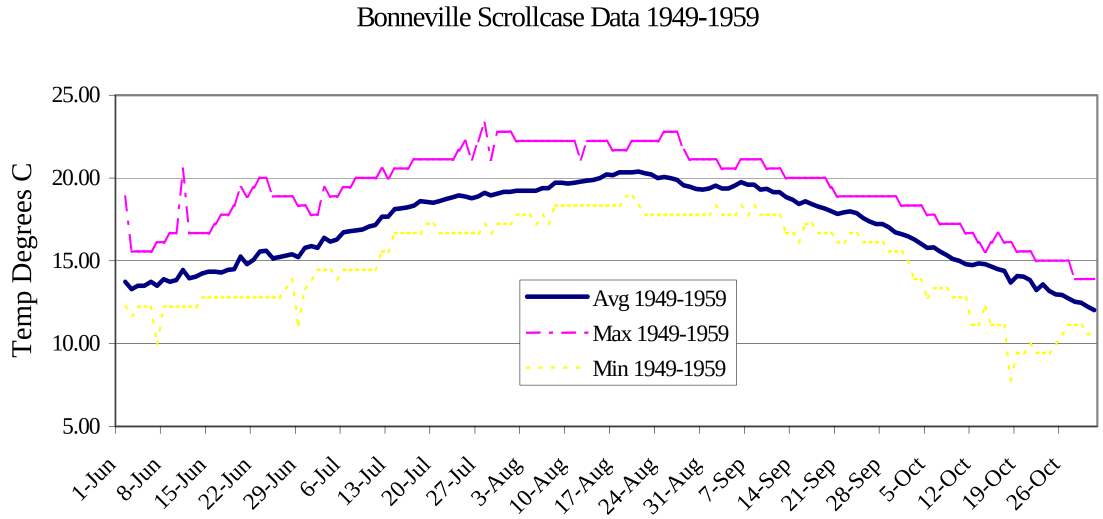

Figure 1. Maximum, minimum, and average Bonneville Dam Scrollcase temperatures 1949-1959 as reported at DART.

	% of Days when Avg. Temp >= 20C	
	1957	
	July	August
Clarkston, WA	61%	84%
Oxbow Dam Site	100%	87%
Brownlee Dam Site	100%	84%

Table 2. Percentage of days when average daily water temperature exceeded 20°C between the upstream and downstream ends of Hells Canyon.

E-2 Current Mainstem Water Temperatures

The Corps believes that water temperatures in the Snake and Columbia mainstem rivers are warmer today than they were historically. However, the Corps also believes that to characterize hydropower development as the only reason current temperatures are warmer than historic is incorrect. The Corps believes that water temperatures are warmer because of three major factors including:

1. Construction and Operation of the Federal and Private Columbia/Snake Mainstem Dams
2. Climate Changes
3. Upstream Influences

E-3 Mainstem Dam Construction and Operation

The presence of dams has modified natural temperature regimes in the mainstem Columbia and Snake River Basin reservoirs. They are known to have affected water temperature by extending water residence times and by altering the heat exchange characteristics of affected river reaches (Yearsley 1999). Some of the most significant changes to the river include the change of cross sectional area, slowing of water velocities and the alteration of the seasonal hydrograph. Of concern to the region are the water temperatures from July through November. This is due primarily to the biological impacts of the yearly peak of warm water temperatures, as well as the extended period of time when water is warmer than under a natural hydrograph scenario.

Seasonal temperature fluctuations generally decrease below larger reservoirs that are thermally stratified and have hypolimnetic discharges. Downstream temperatures are cooler in the summer as cold hypolimnetic waters are discharged, but warmer in the fall as energy stored in the epilimnion during the summer is released (Spence et al. 1996). Thus, operation of storage reservoirs affects both the thermal characteristics of the river and the thermally regulated aspects of salmon survival. For this reason, the thermal effects of reservoir operation are an important consideration in developing system operations aimed at protecting and restoring listed salmonids.

Maximum temperatures in the mainstem Snake River, where salmon survival is most tenuous, are generally lower in summer than before the series of storage and mainstem reservoirs was installed. This is also true in the mainstem Columbia River The assumption that temperatures may have increased is correct when applied to temperatures seen in late summer and fall, when the latency of reservoir storage is exhibited. Besides a lowering of maximum summer temperatures, the peak temperatures have been shifted to later in the year. Localized temperature increases have been caused by the hydropower system. In particular, shoreline areas inhabited by underyearling Chinook salmon during their summer rearing and outmigration have increased. (ISG 2002)

The Program also seems to assume that river temperature is linked to volume of flow and water velocity. These are not necessarily linked. Thalweg temperature (the temperature of most of the water volume) and its timing are affected by water storage and release schedules.

Localized temperatures and their cumulative effects on thalweg temperatures are affected by reservoir topography more than by river flow rates. (ISG 2000)

During the summer, water temperatures within the Lower Snake reservoir system have a 1 to 2°C smaller day and night temperature fluctuation than upstream inflow to the Lower Granite reservoir. Daily temperature fluctuations in this reach range from roughly 0.5 to 1.5°C in the upstream reach to day and night temperature fluctuations below the reservoir system of approximately 0.4 to 1.0°C (0.7 to 1.8°F). In addition, temperatures at any point within the lower Snake River reservoir system are typically zero to 2°C warmer or cooler than the Snake River water flowing into the reservoir system at the Lower Granite reservoir depending on the time of year, location, flow conditions, current flow augmentation and temperature control operations, and voluntary spill/power operations (Corps 2002).

Average water temperatures within the reservoir system warm slower by approximately 1 week and cool slower by approximately 2 weeks than the Snake River water flowing into the Lower Granite reservoir. Flow augmentation with cold water from the Dworshak reservoir on the North Fork Clearwater River is effective in reducing water temperatures in the Lower Granite reservoir. (Corps 2002)

E-4 Climate Changes

Peery et al 2002 used recently collected and historic data to evaluate effects of warm water conditions on passage of adult salmon and steelhead in the lower Snake River, especially in relation to temperature exposures in fishways. They reported, "temperatures in the forebay of Ice Harbor Dam have trended upwards in the fall (September and October) since 1962, which can be explained at least partially by an increase in air temperatures during August and September in the region since 1948."

In addition, Petersen and Kitchell (2001) reported in great detail, "large-scale climate oscillations, or regime shifts, have likely caused water temperature in the Columbia River to vary several degrees between 1933 and 1996" and "average June July temperatures in the Columbia River during 1954-1990 were significantly correlated with temperatures in the Fraser River in British Columbia. Since the Fraser River has not had extensive hydro development, this correlation suggests regional temperature control…" They also reported "an index for the Columbia Basin suggested that climate shifts occurred in 1946, 1958, 1969, and 1977". They also reported, "Beginning about 1975, summer water temperatures have risen steadily, suggesting broad scale climate effects, since all dams were operational by the early 1970s…"

E-5 Upstream Influences

Numerous upstream activities are believed to have influenced water temperatures in the Columbia River basin. These include the construction and operation of upstream dams, point source returns, agriculture practices, forestry practices and urban development. Although some of these contributions may be small, the cumulative effects of these temperatures all contribute to overall river temperature at the mouth. For example, in a 1971 EPA study, “temperatures of the Columbia River in Canada will be affected by the regulation of Mica and Arrow lake dams on the Mainstem Columbia… ” (EPA 1971) Although the extent of the impacts to mainstem Columbia temperatures in the U.S. are uncertain, the Corps believes that there may have been some substantial impacts. For example, Anglin et al 1999 reported that the hydrograph of the Columbia River at the Priest Rapids Gage was not significantly altered until after the completion of the Canadian hydrosystem. The Corps believes that this has had an affect on temperatures as well. From the Rock Island Scrollcase data for the same periods, temperature differences can be seen.

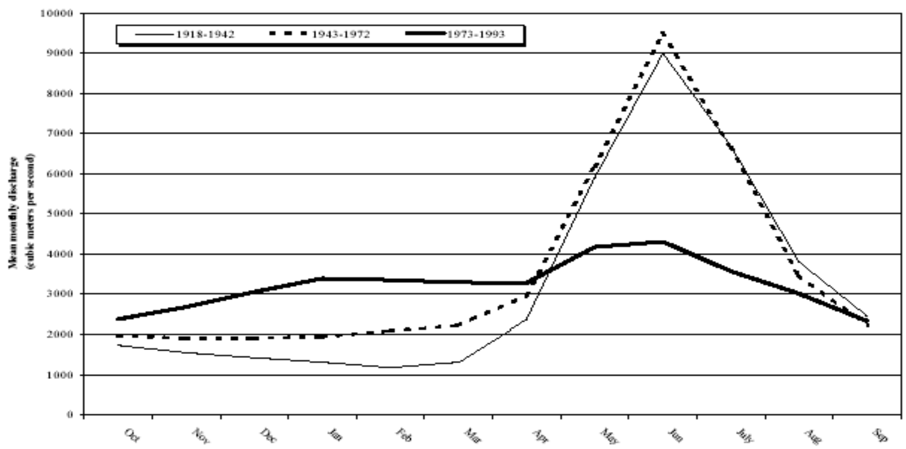

Figure 2. Columbia River Hydrograph as measured at Priest Rapids Gage. Time periods designate pre-Grand Coulee, Grand Coulee to Mica Dam, and post Mica Dam.

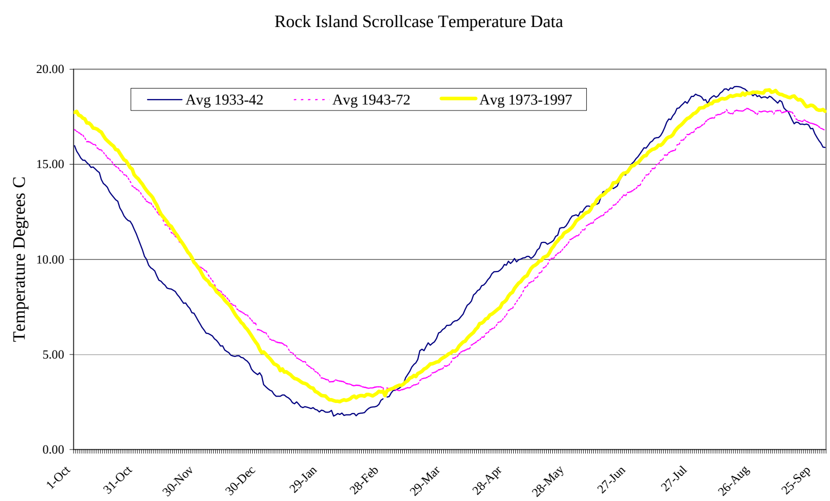

Figure 3. Columbia River average daily temperature as measured at Rock Island Dam scrollcase. Time periods designate pre-Grand Coulee, Grand Coulee to Mica Dam, and post Mica Dam completion.

APPENDIX F - COORDINATION OF THE DRAFT PLAN

The draft Plan has been coordinated with the following agencies or entities.

Bonneville Power Administration
Bureau of Reclamation
Chelan County Public Utility District

Columbia River Inter-Tribal Fish Commission
Confederated Tribes of the Colville Reservation
Douglas County Public Utility District
D. Rohr and Associates
Fish Passage Center
Grant County Public Utility District
Idaho Department of Environmental Quality
Idaho Power Company
NOAA Fisheries
Nez Perce Tribe
Northwest Power and Conservation Council
Oregon Department of Environmental Quality
Pacific Northwest National Laboratory
Spokane Tribe of Indians
U.S. Environmental Protection Agency
U.S. Fish and Wildlife Service
Washington Department of Ecology