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

Interim Update of the 2004 Plan

Prepared by:

U.S. Army Corps of Engineers, Northwestern Division
Planning, Environmental Resources, and Fish Policy and Support Division
Portland, Oregon

With Input and Cooperation from:

Bonneville Power Administration
Bureau of Reclamation
Chelan County PUD
Douglas County PUD
Environmental Protection Agency
Fish Passage Center
Grant County PUD
Idaho DEQ
Idaho Power Company
NOAA Fisheries
Oregon DEQ
U.S. Fish and Wildlife Service
Washington DOE

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0 Introduction

In Appendix B of the National Marine Fisheries Service (NMFS, also National Oceanic and Atmospheric Administration Fisheries [NOAA Fisheries]), 2000 Biological Opinion (BiOp) for Operation of the Federal Columbia River Power System, 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 TDG and temperature improvements to the Columbia River Basin, mainly in the portions of the Columbia, Snake, and Clearwater rivers where Federal dams exist. This commitment was continued in the NOAA Fisheries 2004 BiOp and the Action Agencies' 2004 Updated Proposed Action (UPA). The Water Quality Plan for Total Dissolved Gas and Water Temperature in the Mainstem Columbia and Snake Rivers (Plan) was included in the UPA as Appendix A. This update of the 2004 Plan has been prepared by the Corps through coordination with and input from numerous other state and federal agencies, tribes and private entities, as shown in Table 0-1. In addition to meeting BiOp measures, the updated Plan is being provided to the States of Oregon and Washington as they process waivers and rule modifications for the States' Water Quality Standard (WQS) for Total Dissolved Gas (TDG).

Table 0-1. Agencies coordinating and cooperating with the development of the water quality plan for Appendix B of the NMFS BiOp.

Federal	State	Tribal	Private
Bonneville Power Administration	Idaho DEQ	Nez Perce Tribe	Chelan County PUD
Bureau of Reclamation	Oregon DEQ		Douglas County PUD
Environmental Protection Agency	Washington DOE		Fish Passage Center
NOAA – Fisheries			Grant County PUD
US Fish and Wildlife Service			Idaho Power Company
			Pacific Northwest National Laboratory

EPA, NOAA Fisheries, USFWS, and the Action Agencies intend to integrate their fish and wildlife and water quality efforts in the form of actions to support the objectives and responsibilities of the ESA, CWA, and other fish and wildlife and water quality statutes such as the Northwest Electric Power Planning and Conservation Act. The plan is anticipated to be consistent with the Columbia and Snake River mainstem Total Maximum Daily Load (TMDL) limits that have been completed or are currently being developed by EPA, the states, and the Tribes and focuses primarily on the physical and operational changes to both Federal and non-Federal dams that may benefit water quality in terms of temperature and dissolved gas while improving the survival rates of ESA-listed species. This plan was prepared to satisfy the commitments of the Federal Action Agencies as outlined in the NOAA Fisheries BiOp.

0.1 Goals

The goals of the Plan are as follows:

• 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, with the long-term goal of attaining WQS and TMDLs developed by EPA, the states and Tribes.

• To provide a framework for identifying, evaluating, and implementing technologically and economically feasible actions for dam operators to use as they work toward reducing water temperature and total dissolved gas levels.

• To provide a record of the actions that are and are not feasible for structural and operational improvements aimed at improving water quality conditions and meeting water quality standards. This information may provide a basis for future beneficial use and water quality criteria revisions.

• To bring basin wide information into the decision processes regarding total dissolved gas and water temperature, and to provide technical assessment of a project's relative value in terms of water quality.

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

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 to ongoing TMDL development activities on the mainstem and in the sub-basins.

Total Dissolved Gas (TDG)

1 Introduction

The problem of supersaturation of Total Dissolved Gas (TDG) occurs in many rivers throughout the world, but has been noted to be a particular problem in the Columbia River Basin. This excess gas can be a serious threat to the health of aquatic life subjected to it. The exposure of fish to excess dissolved gas can produce 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. As a result, the Transboundary Gas Group is facilitating the co-operative efforts of the United States and Canada to undertake various measures that will reduce the amount of dissolved gas in the Basin (Goldschmid 2001).

TDG has been the primary water quality parameter monitored by the Corps to meet WQS and protect the recognized or designated beneficial uses of the states of Idaho, Oregon and Washington. The designated uses include aquatic life, water supply, recreation, wildlife habitats, and aesthetics. High saturation level TDG can cause physiological damage to fish. Water temperature is also measured because it affects TDG saturation levels, and because it influences the health of fish and other aquatic organisms. The Columbia River is listed as an impaired water body on the States' 303(d) list for temperature and total dissolved gas. Both TDG and water temperature are closely linked to water management operations (e.g. water released over the dam spillways, releases through the powerhouses and other facilities, and forebay and tailwater water surface elevations) at Corps projects.

The NMFS 2000 BiOp on the operation of the Federal Columbia River Power System (FCRPS) established a conservation measure for the development of a Water Quality Plan for the mainstem waters of the Clearwater, Snake and Columbia rivers that are directly impacted by federal dams. The goal of the plan, as outlined in Appendix B of the BiOp, was to outline the physical and operational changes that could be used to improve the overall water quality in these rivers, and to conserve threatened and endangered species, thus meeting the requirements of both the Clean Water Act (CWA) and the Endangered Species Act (ESA).

This TDG document presents background on TDG issues in the Columbia River Basin, the rationale for preparing the document, what can be and has been done to address and resolve TDG issues, and what the Corps' planned schedule is for addressing these issues. This document is also being prepared to aid the states of Oregon and Washington in preparing TDG waivers and rule modifications (Section 1.4). This document is composed of five major categories, including:

1) The background of TDG in the Columbia and Snake rivers, the goal of the NMFS 2000 FCRPS BiOp and Total Maximum Daily Loads of TDG.
2) The monitoring of TDG in the area covered by the plan, a description of operational and physical changes that can be made at the hydroprojects that have potential to lower TDG levels, a description of the numerical models that can be used to look at dissolved gas in the system, and studies and programs of how these goals are examined and accomplished.

3) Discussion of the current configurations of the primary FCRPS hydroprojects, how they are operated and a schedule of past and proposed future TDG related improvement measures to meet WQS.
4) A brief discussion addressing the Reasonable and Prudent Alternatives in the BiOp that are being addressed by this work and the long-term non-BiOp strategy to get TDG levels to 110%.
5) A final summary and appendices.

1.1 Background

When water is spilled over a spillway at a dam, it entrains bubbles of air. 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.

Spilling water at dams may be done voluntarily or involuntarily. Voluntary spill occurs primarily to assist juvenile salmon migration at mainstem run-of-river projects. This 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 either due to the physical limitations of the system, because the flow exceeds the hydraulic capacity of the powerplant (can be further limited by generator units out of service), 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.

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. 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 during the time when the units are being aspirated normally during low turbine discharges.

In the years just after the completion of the four lower Snake River dams, with both the absence of flow deflectors in most locations and high river discharge levels, smolt survival through the hydrosystem was quite low. For example, in some years during the late 1970's, inriver survival estimates for juvenile Snake River Chinook salmon and steelhead from Lower Granite to Bonneville Dam was under 5% (Corps 2002b - Lower Snake River Feasibility Report) some of which was attributed to high TDG in the lower Snake River. Current estimates of survival in normal flow years, however, are from 40-60% inriver survival. Coupling this with the 98% direct survival of juvenile salmon that are transported from the lower Snake River Dams, has yielded substantially better survival rates for fish than when the dams were first completed. The improvements in fish passage and implementation of the strategy to pass migrating juvenile fish over the spillway despite causing TDG levels in excess of the states water quality standard of 110% probably helped to improve juvenile survival.

1.2 TDG and the Corps of Engineers

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 February 1996 (Corps 1996). The Corps policy is to comply with 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 listing of certain Snake River salmonids under the ESA beginning in 1991, the Corps implemented a variety of operational and structural measures to improve the survival of listed stocks. The National Marine Fisheries Service (NMFS) 1992 BiOp called for providing summer releases of available water for flow augmentation for migrating juvenile salmon. Spill for fish at the lower Snake River projects was limited to Lower Monumental and Ice Harbor dams. In 1994, the program was further expanded in response to the NMFS request to release water over the spillways at the lower eight Columbia and Snake rivers mainstem dams to a level of 120% TDG where State rule modifications, variances 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 during the ESA consultation in 1994. In a letter from the Corps to the NMFS, dated November 9, 1994, the Corps stated that "Spill for fish passage at Corps projects will be provided in 1995 according to the Fish Passage Plan (FPP) criteria, including any modifications agreed upon in consultation under the [ESA]…Also, any necessary waivers of water quality standards must be obtained beforehand from appropriate State or Federal authorities..."

The Corps' 1995 Record of Decision (ROD) and the 1998 Record of Consultation and Summary of Decision (ROCASOD) adopted the recommendations of the NMFS 1995 BiOp, and the 1998 Supplemental BiOp, respectively. Relevant sections of the 1995 and 1998 BiOps regarding operations that impact TDG levels and water temperature include:

Reasonable and Prudent Alternative (RPA) #2 in the 1995 BiOp identified additional voluntary spill at the lower Snake River projects to achieve 80% Fish Passage Efficiency (FPE) and survival of migrating juvenile salmonids (1995 BiOp, pages 104 - 110). At certain projects, voluntary spill up to 110% TDG would not achieve 80% FPE. Therefore, in recommending the spill levels above the State water quality standard of 110%, NMFS considered the risks of the elevated levels of TDG on migrating salmon versus higher levels of turbine passage and decided the tradeoff was acceptable.

In the 1998 Action Agency Biological Assessment, it was proposed that voluntary spill be minimized at lower Snake River projects due to concerns of high TDG and to maximize fish transportation by barges. During consultation with NMFS this proposal was amended and the 1998 Supplemental BiOp increased the voluntary spill levels partially based on observations made after 1995. "NMFS also believes that moving past the per-project FPE goals (stated in the 1995 RPA) to further increase juvenile survival would not violate the intent of the requests to the State water quality agencies for dissolved gas waivers." (98BiOp, page c-4) NMFS recommended maximum spill up to the higher TDG levels rather than curtailing spill when 80% FPE was achieved, which the Corps agreed to implement. (98ROCASOD) The NMFS 1998 BiOp also asked the Corps to test increasing voluntary spill at John Day Dam from 12 hours to 24 hours. The Corps initiated those studies during the 1999 spring migration.

The Corps and Reclamation recommend coordinating with 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, and 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.

1.2.1 Mainstem Water Quality Plan Workgroup

The 2000 Biological Opinion observed the complementary features of the ESA and the CWA. It was recognized that an assertive implementation 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 NOAA Fisheries, EPA, USFWS and the Action Agencies called for the integration the Biological Opinion water quality actions with the relevant objectives of the CWA and other fish and wildlife and water quality statutes. The mechanism by which this integration could occur was through the development of a mainstem water quality plan.

The Biological Opinion Section 9.6.1.7 and Appendix B charted a course for the development of a comprehensive Columbia and Snake River water quality plan. This commitment was renewed in the 2004 UPA and BiOp. From the outset of the planning effort it was clear that the scope of the mainstem plan would be broader than the RPAs and would include additional actions to improve mainstem water quality by reducing total dissolved gas and water temperature. Appendix B of the Biological Opinion tabulated actions required to avoid jeopardy as well as those actions that are beyond the scope of the RPAs. However, although Appendix B is not itself a water quality plan it does suggest the procedure for the development of a plan toward attainment of water quality standards in the Federal Columbia River Power System.

Furthermore, it was anticipated that a mainstem water quality plan would include Columbia and Snake River TMDL limits currently under development by the states, tribes and EPA.

To this end a Mainstem Water Quality Plan Workgroup (Workgroup) was formed in 2001 and has met periodically since to coordinate updates of the 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 Federal Columbia River Power System, 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 total dissolved gas variances 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.

Simultaneous to the early meetings of the Workgroup and the drafting of the above statements, the Northwest Power and Conservation Council conducted a solicitation for projects implementing the Mainstem Provincial Review. The Workgroup reviewed the water quality projects responding to the solicitation and offered policy guidance regarding the proposals to the Power Council and the Columbia Basin Fish and Wildlife Authority. The Workgroup then focused attention on the drafting of the Mainstem Water Quality Plan.

1.2.2 <u>Water Quality Team</u>

The Mainstem Water Quality Plan Workgroup may have specific technical issues arise as they pursue regional water quality planning and policies. Examples of technical issues could include but would not be limited to total dissolved gas or water temperature improvement topics, research needs or designs, monitoring strategies, or TMDL compliance concerns. In these instances the existing NOAA Fisheries technical Water Quality Team operating in support of the Biological Implementation may be called on for assistance. The Workgroup could also communicate with the other technical teams serving the NOAA Fisheries and the regional Implementation Team. These teams include the System Configuration Team and the Technical Management Team regarding issues of Federal Columbia River Power System modification and operation, respectively.

1.2.3 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

The TGG continues to meet twice each year, usually in the early Spring and again in the Fall. 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

1.3 2000 and 2004 FCRPS Biological Opinions

The Final 2000 NMFS and USFWS BiOps for operations of the Federal Columbia River Power System (FCRPS) stated: "The two agencies intend the recommendations and requirements of these opinions to be mutually consistent. They represent the Federal biological resource agencies' recommendations of measures that are most likely to ensure the survival and recovery of all listed species and that are within the current authorities of the Action agencies."

According to the USFWS 2000 BiOp, operational and structural changes are to be made to reduce uncontrolled spill and the effects of high levels of TDG at lower Columbia River dams if it is determined that bull trout are affected by the FCRPS.

The NMFS 2000 BiOp identified metrics that were indicative of juvenile fish survival to meet system-wide performance objectives consistent with actions likely to avoid jeopardizing the continued existence of 12 listed fish species in the Columbia River Basin. To achieve the objectives of the BiOp, NMFS developed the jeopardy analysis framework. It was recognized that, in many instances, actions taken for the conservation of ESA-listed species also move toward attainment of State TDG and water temperature standards.

There were 14 RPAs (namely, RPAs 130 to 143) identified as part of a water quality strategy in the NMFS 2000 BiOp. Specifically, RPAs 131 and 132 dealt with water quality monitoring. RPA 131 indicated that the physical and biological monitoring programs are to be developed in consultation with the NMFS Regional Forum Water Quality Team and the Mid-Columbia Public Utility Districts (PUDs). RPA 132 specified that a plan be developed to perform a systematic review and evaluation of the TDG fixed monitoring stations (FMSs) in the forebays of all the mainstem Columbia and Snake River dams.

Appendix B of the 2000 NMFS BiOp was meant to address conservation measure actions in the mainstem Columbia River that go beyond the ESA guidelines. The Appendix B geographic scope ranged from the International Border to the Bonneville Dam tailrace, in the mainstem Snake River from Brownlee Dam to the mouth and in the Clearwater River from Dworshak Dam to the mouth. In Appendix B, NMFS indicated that their goal was to get TDG levels to no more than 110% for river discharges up to the 7-day, 10 year high flow in all critical habitat of the basin.

In developing the BiOp, however, the goal of NMFS was also to consider the respective ecological objectives of both the CWA and ESA. In many instances, the goals of the two acts are mutually inclusive in that many of the benefits of appropriate levels of dissolved gas and temperature can be realized by the endangered species within the system. However, despite the overlap, there may be actions that help to meet the CWA that have detrimental, little, or no effects on endangered fish species. Conversely, increased spill to meet ESA objectives can have a detrimental effect on meeting WQS.

In June 2003, the Federal District Court remanded the 2000 BiOp to NOAA Fisheries for revisions. NOAA Fisheries revised and updated its jeopardy analysis for listed salmon and steelhead. Based on the updated analysis, the Action Agencies prepared an Updated Proposed Action (UPA) on FCRPS operation (USACE [Corps] et al. 2004). The UPA was finalized in November 2004. A revised NOAA Fisheries BiOp was then issued, also dated November 2004 (NOAA Fisheries 2004). The Action Agencies are currently operating projects and marketing energy from the FCRPS under the 2004 BiOp/UPA. To a large extent, the 2004 UPA continues the implementation of the actions contained in the 2000 BiOp, including those actions related to water quality improvements for TDG and temperature. Because of the continuation of measures in the 2000 BiOp, this Plan continues to refer to measures in that BiOp. The UPA also stated that actions identified in the Water Quality Plan will be implemented to make further progress towards meeting water quality standards for TDG and water temperature.

In May 2005, the Federal District Court invalidated the 2004 FCRPS BiOp. In October 2005, the Court remanded the BiOp to NOAA Fisheries to produce a BiOp consistent with the Court's order by October 2006. The deadline was later extended to February 2007. The Court also ordered NOAA Fisheries and the Action Agencies to collaborate with sovereign states and tribes on the development of a new proposed action and a jeopardy framework. During the remand, the Court left the 2004 BiOp in effect. Remand discussions are now occurring, both to determine annual river operations and longer range actions to protect ESA-listed fish species. The Actions Agencies continue to operate according to the 2004 BiOp and UPA, as per the Court's order.

1.4 Variances to the TDG Standards

One of the components of the NMFS 2000 BiOp water quality strategy was for the Corps to take the actions necessary to implement the spill program at the dams called for in the BiOp, including obtaining TDG variances from appropriate State water quality agencies. These variances would adjust the TDG criteria when "voluntary" spill is required to assist juvenile salmonids transport past Corps projects. Since 1996, the states have provided waivers and rule modifications, 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 Corps also addressed variances to the TDG WQS with the States and tribes impacted by the program implemented in the FCRPS for which the Corps has responsibility. A regional water quality plan group worked in 2002 to develop a regional water quality plan that this document represents. The Corps is developing its component portion of the regional water quality plan and preparing documents that would support the need for the states of Oregon and Washington to adjust TDG criterion or issue TDG waivers. Under the TDG TMDLs, TDG waivers are a temporary fix to the long-term goal of attaining water quality criteria (110% TDG saturation) with structural and operational modifications at the lower Columbia and Snake River dams.

1.5.1 Idaho

The State of Idaho was approached in 2001 concerning a variance to water quality standards. The State, in conjunction with the tribes, provided a set of conditions that must be met as part of the variance 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 variance by the Corps after the 2001 water year. The State WQS of 110% for TDG is generally met.

1.5.2 Oregon

Oregon TDG water quality standards state:

OAR 340-041-0031

Total Dissolved Gas

(1) Waters will be free from dissolved gases, such as carbon dioxide hydrogen sulfide, or other gases, in sufficient quantities to cause objectionable odors or to be deleterious to fish or other aquatic life, navigation, recreation, or other reasonable uses made of such water.

(2) Except when stream flow exceeds the ten-year, seven-day average flood, the concentration of total dissolved gas 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 total dissolved gas relative to atmospheric pressure at the point of sample collection may not exceed 105 percent of saturation.

The Corps took appropriate actions for attaining a water quality waiver from the State of Oregon for the 2002-2007 spill seasons. The first Federal request for a TDG waiver was submitted to the Oregon Department of Environmental Quality in 1996. The most recent request, in 2002, 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, subject to specific conditions, as signed by Stephanie Hallock on March 8, 2001. A waiver of the TDG standard for the Columbia River was provided from midnight on April 1, 2002 to midnight August 31, 2002. The Commission approved a TDG waiver for the Columbia River of a daily (12 highest hours) average of 115% as measured in the forebays 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 Oregon Department of Environmental Quality 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 Oregon Department of Environmental Quality no later than December 31, 2002.

On December 23rd, 2002, the Corps submitted information for a multi-year TDG waiver to the Oregon Department of Environmental Quality. 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 variance. This new waiver was in effect from April 1 through August 31 of each year through the 2007 spill season.

The Federal Agencies are again providing information to the Oregon Department of Environmental Quality for a new TDG waiver. The waiver request will go through a public comment process. Final approval of the requested TDG waiver will be completed by Oregon's Environmental Quality Commission in the summer of 2007.

1.5.3 **Washington**

In its 1997 water quality standards, the State of Washington modified its rule on total dissolved gas to allow for adjusted TDG criteria when spilling water over dams to aid fish passage. This new rule (WAC 173-201A-060(4)(a)), states 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 requires that, when spilling water at dams is necessary to aid fish passage, total dissolved gas 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. Total dissolved gas 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 total dissolved gas. In addition, there is a maximum total dissolved gas one hour average of one hundred twenty-five percent, relative to atmospheric pressure, during spillage for fish passage.

In December 2002, the Corps submitted a package to the WDOE to satisfy the requirements for a TDG rule modification. In a letter to the Corps of Engineers 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 December 2003, the Corps submitted another package to the WDOE which contained a Water Quality Plan which was greatly expanded and covered a period extending through 2015. In response to this submittal, the WDOE approved another one-year TDG rule exemption beginning February 27.

On January 14, 2005, the Corps submitted another package of documents intended to satisfy the State of Washington's requirement for a TDG rule modification. 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 modification for a period of three years (through February 2008).

In addition to the TDG requirements described above, as part of the approval of the Water Quality Plan and granting of the rule modification for three years, the Corps was expected 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.

1.6 **Total Maximum Daily Loads (TMDLs)**

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.

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 obligatory once a water is identified as impaired, i.e. not meeting WQS.

The water quality standards for both Oregon and Washington include the same TDG criterion: *110 percent of saturation not to be exceeded at any point of measurement.* This criterion does not apply to flows above the seven-day, ten-year frequency flow (7Q10) flood flow. In addition, special waiver or rule modification 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 waiver limits on an annual basis. Because the waiver limits are either temporary or annually renewed, this TMDL addresses only the 110 percent criterion. However, the implementation plan allows compliance with waiver limits through 2010 as an interim allowance for compliance with the TMDL in the short-term.

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 dam spills 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.

Long-term compliance with load allocations for dam spills 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 must be met in the spill from each dam individually at a specified compliance location, with allowance made for degassing in the tailrace below the spillway and above the compliance location.

Compliance with load allocations are tied to structural changes at each dam, and are intended as long-term targets. Short-term compliance is established under the implementation plan, and is based on operational management of spills, implementation of the “fast-track” DGAS structural modifications, and compliance with Endangered Species Act requirements and TDG waiver criteria.

TMDL implementation plans, also called Water Quality Management Plans (WQMP), are developed by States to achieve the load allocations identified in the TDG TMDL. Implementation actions include the NPDES Permit Program, State Water Quality Certification Programs, State Non-point Source Management Programs and other mechanisms. For Columbia/Snake Mainstem TDG TMDLs, implementation plan development was done by the States with implementation by the Corps. Washington State's Department of Ecology and Oregon State's Department of Environmental Quality will oversee implementation of this TDG TMDL. They will work collaboratively with each other, as well as with the U.S. Army Corps of Engineers, tribal, and other state and federal agencies towards implementation of the TDG TMDL.

Further progress in TDG 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 desired that this Water Quality Plan will form the foundation for TMDL implementation plans for the Columbia and Snake rivers.

1.7 Existing TDG TMDLs

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

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

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

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

1.8 Anticipated TDG TMDLs

One additional TMDL for TDG is anticipated within the near future. A plan for the Pend Oreille River, from the Washington-Idaho border to the Washington-Canadian border, is currently in progress and is being compiled by the Washington Department of Ecology (WDOE).

2 Monitoring/Modeling/Operations/Structures

2.1 Physical Monitoring

The Corps' Plan of Action for TDG Monitoring for 2007 can be found in Appendix D. This plan is produced annually in coordination with the Regional Forum Water Quality Team and provides greater detail for those who are interested. 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. the Bureau of Reclamation, Douglas County PUD, Chelan County PUD, and Grant County PUD).

2.2 Purpose of TDG Monitors

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

a. 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.
b. 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.
c. 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.
d. To provide data of known quality to enhance analytical and predictive capability of existing models/tools used to evaluate management objectives.

2.3 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. 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 sample conditions representative of the total river.

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.

Excerpt from the 2002 TDG TMDL:

Routine monitoring of instream TDG levels occur at fixed monitoring station (FMS) sites above and below each dam for compliance with the TDG TMDLs and waivers. The tailwater FMS sites in some cases may be a mile or two downstream of the dam. The FMS sites have been the primary point of compliance and assessment of TDG levels, especially for compliance with waiver limits during fish passage spills. The locations have been chosen for a variety of reasons, a primary one being the logistics and feasibility of long-term monitoring. However, studies suggest that some of these sites are not collecting data that are representative of river conditions. The FMS sites will continue to be the primary location for determining compliance with waiver limits used for fish passage management. For the purposes of TMDL compliance, TMDL needs do not need to drive FMS siting issues.

The interagency Water Quality Team manages issues regarding the fish passage program and FMS. The Water Quality Team is charged with providing technical advice and guidance on temperature and total dissolved gas water quality in the context of the NMFS 2000 Biological Opinion relating to the Columbia River Hydropower System. The TDG measurements at a given location in the river are influenced significantly by environmental factors such as water temperature, biological productivity, barometric pressure, and wind, as well as the spill. The Water Quality Team will continue to study and discuss these issues in order to achieve a mutually satisfactory monitoring end product.

Short-term compliance and the effectiveness of operational implementation actions will be monitored at existing fixed monitoring station sites. The current fixed monitoring station TDG monitoring system consists of tailrace and forebay monitoring stations at each mainstem lower Snake and Columbia River dam and at key locations in some tributaries. While most of these stations do a credible job of reporting meaningful data, some have been shown to be questionable. This system is now undergoing a thorough review by the National Marine Fishery Service's Water Quality Team. Screening criteria will be developed and used to evaluate all existing monitoring stations. Stations that do not conform to these criteria will be relocated to more appropriate locations. This screening process will include consideration of how well the station represents TDG and water temperature in a given river reach and how sensitive the station is to non-spill factors that affect TDG, such as temperature and aquatic plant respiration.

2.4 <u>Results of Annual Physical Monitoring</u>

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 have made the annual reporting of the biological and physical monitoring a 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 .

2.5 BiOp TDG Physical Monitoring Requirements - RPA Action Item 132

The 2000 BiOp Reasonable and Prudent Alternative (RPA) Action Item 132 required the Action Agencies to develop a plan to conduct a systematic review and evaluation of the total dissolved gas (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. The Action Agencies, NOAA Fisheries and the Washington Department of Ecology formed a special Fixed Monitoring Subgroup (FMSg) of the Water Quality Team to aid the implementation of Action Item 132.

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."

One issue that still 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 the representativeness of 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 general representativeness of the six forebay TDG fixed monitors, two at McNary and one at each of the other four projects. 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 were problematic 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.

The primary recommendations for improving the forebay FMS operation and representativeness were threefold (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 is 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. This would be adequate to avoid thermal responses in the TDG pressure readings brought about 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, the subgroup recommended that the 2004 spill year be used as a transition year for Walla Walla District's FMS forebay monitors. To that end they recommended that the existing FMS forebay monitors at these projects continue to be used to manage spill for 2004. Monitors were also deployed for the 2004 spill season at the following 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.

Currently, the single remaining TDG monitoring site issue is the location and use of the Camas/Washougal site to manage spill at Bonneville Dam. The location and use of this site has been a point of contention for a number of years. Discussions within the WQT continue on this site.

3 Biological Monitoring

3.1 Results of the 2005 TDG Biological Monitoring

Biological monitoring of juvenile salmonids in 2005 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 mid-June at the Snake River sites, when the numbers of steelhead and yearling Chinook were too few to sample effectively. Subyearling Chinook were not sampled in the lower Snake River due to their endangered status and because the Biological Opinion does not call for the implementation of summer spill at the Snake River collector projects. Sampling of subyearling Chinook did occur at Columbia River sites until the end of August.

In 2005, a total of 11,428 juvenile salmonids were examined for GBT between April and August. A total of 52 or 0.46% 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 2005 reflected changes in TDG conditions in the river from year to year. In 1995 no fish had severe fin GBT and 1995 had the lowest number of days with high TDG. Also the occurrence of severe signs in 1996 and 1997, and the increase in exceedances of the NMFS action criteria, reflected a significant increase in the number of days when TDGS rose above 125% in the forebays of these dams. While in 1998 only 4 fish were found with severe fin GBT and 1 fish in 1999, reflecting the more moderate conditions found in the river. (Corps 2002a)

3.2 Biological Monitoring Plan for 2007

Biological monitoring in 2007 for GBT will be the same as that which occurred in 2006 and previous years. Sampling would occur at Bonneville, McNary, Rock Island, Lower Granite Little Goose and Lower Monumental Dams as mentioned in section 2.2.1.

3.3 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 inriver conditions over longer reaches than the physical models can accommodate.

3.3.1 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. Among other various 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. Other concerns that have been tested using the physical models include but are not limited to RSWs and spillway/powerhouse divider walls.

3.3.2 <u>Mathematical Models</u>

Two mathematical models (MASS1 AND MASS2) were developed by Battelle Pacific Northwest Laboratories and utilized during the Dissolved Gas Abatement Study (DGAS, See section 2.4). 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 and could be used for real-time decision-making but would need further work to provide user manuals and interface. A simpler spreadsheet model (SYSTDG) was also developed as a result of the DGAS study. This model was intended to be used as an operational decision making tool. Development is ongoing.

3.3.3 <u>MASS 1</u>

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 and only single values of water surface elevation, discharge, velocity, concentration, and temperatures are computed at each point in the model, at each time interval.

3.3.4 <u>MASS 2</u>

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).

3.4 <u>SYSTDG</u>

The Corps of Engineers and the Bureau of 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 need for a system model of TDG was outlined in the 2000 Draft BiOp to assist spill and TDG management planning throughout the Columbia River Basin.

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.

3.5 Dissolved Gas Abatement Study (DGAS)

The Dissolved Gas Abatement Study (DGAS) is 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 and a Phase II 30% report was released in 1997. It identified a shift from the 110% goal to a new goal designed to reduce TDG to the extent economically, technically, and biologically feasible. A 60% report on Phase II of the DGAS was released in 1999. A draft final Phase II report was distributed for review and comment in April 2001 and the study 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 recommended 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.

3.6 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 2-2. A more detailed discussion of modifications being considered at individual projects follows the table.

3.7 Operations at Hydroprojects

The water quality standard and criterion developed by the states and EPA is 110% of saturation at ambient temperature and pressure. The Corps' policy is to operate each mainstem project to meet state standards insofar as physically possible unless other overriding reasons cause temporary deviations, such as powerhouse or unit outages, debris spills, special fish operations, etc. The Corps also recognizes that the NOAA Fisheries BiOp and Action Agencies UPA call 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. TDG levels are provided to the TMT and summarized for the year in the Corps' annual TDG Monitoring report.

Table 3-1 Summary of the Current Status of the Corps' Gas Abatement Fast-Track Deflector Optimization Program.

Project	Pre-1995 Number of Spillbays with Deflectors	Post-2003 Number of Deflectors	Total Number of Spillbays
Bonneville	13	18	18
The Dalles	SIS[1]	SIS[1]	22
John Day	0	18	20

McNary	18	22	22
Ice Harbor	0	10	10
Lower Monumental	6	8	8
Little Goose	6	6	8
Lower Granite	8	8	8

[1]SIS – Spillway Improvement Study is underway and will analyze various spillway modifications designed to improve juvenile fish survival through The Dalles spillway passage route. Improvements currently being considered include modifications to the baffle blocks and endsill, construction of spillway deflectors and training walls and spill pattern modification.

Presently, the Corps is planning to provide spill for juvenile fish passage at its mainstem projects to protect ESA-listed salmon species as specified by the NMFS BiOp. Target spill levels are developed through consultation with NOAA Fisheries and may be adjusted during the fish migration season as recommended by the Technical Management Team (TMT).

Continuous spill is provided at Bonneville, The Dalles, Ice Harbor, Lower Monumental, Little Goose, and Lower Granite dams for spring and summer outmigrants to meet BiOp measures. Nightly spill is provided at John Day and McNary dams for spring outmigrants, while continuous spill is provided at those projects for summer outmigrants.

3.7.1 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.

3.7.2 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 volumes are estimated on a daily basis so that forebays spill near to, but don’t exceed, 115% and tailwaters 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% TDG, 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 lower Columbia, Snake, mid-Columbia, HGH, and Willamette Projects in that order.

When system wide TDG is at or below 120%, spill for fish passage would be provided up to the 120% TDG spill caps in the following order: McNary, John Day, The Dalles, Bonneville, Lower Monumental, Little Goose, and Lower Granite dams. In addition, spill could occur up to the 110% TDG spill caps at projects outside the lower Columbia River fish migration corridor: Priest Rapids, Rocky Reach, Wells, Rock Island, Wanapum, Chief Joseph, Grand Coulee, and Dworshak dams in that order.

Spill caps for various applicable TDG levels are provided in Table 3-2. 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.

3.8 TDG Exceedances

Due to involuntary spill, exceedances in the TDG standards can occur throughout the year. As described in Section 1.1, involuntary spill occurs either; due to the physical limitations of the

Table 3-2 Spill caps (in kcfs) corresponding to 110-135 % TDG Levels

PROJECT	TDG%	TDG%	TDG%	TDG%	TDG%	TDG%	REMARKS
	110	115	120	125	130	135	
MCN	40	80	170	230	310	450	Modeled
JDA	20	60	110	250	360	600	Modeled
TDA	20	60	110	250	360	600	Modeled
BON (1)	50	65	115	150	225	270	Modeled
IHR	30	45	95	125	180	240	
LMN	10	15	25	95	180	250	
LGS	10	15	20	80	150	250	
CHJ	5	27	30	33	50	70	
LWG	20	30	40	70	90	150	
DWR	3	7	12	15	15	15	
WAN	10	15	20	50	100	200	
PRD	25	30	40	100	210	350	
RIS	5	10	20	30	150 (1)	300	Limited Data
RRH	5	10	20	30	150 (1)	300	Limited Data
WEL	10	15	25	45	130 (1)	250	Limited Data
GCL (2)	0 20	5 25	10 30	20 75	35 120	55 170	
HGH (3)	3	3	3	3	3	3	
HCR	4	4	6	6	6	6	
LOP/DEX	5	5	5	5	5	5	
GPR	2	2	2	2	2	2	

DET/BCL	7	7	7	7	7	7	
PROJECT	TDG%	TDG%	TDG%	TDG%	TDG%	TDG%	REMARKS
	110	115	120	125	130	135	

NOTES: (1) Limit daytime spill to 100 kcfs.
(2) Assume forebay TDG at 120% (top row=outlet, when El<1260'; bottom row=spillway, when El>1260').
(3) HGH spill to 3 kcfs (110% TDG) until further notice.

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. As the term suggests, the Corps has no other alternative but to spill and has little to no control over when this might occur.

When TDG exceedances do occur, spill caps are changed to reduce spill in order to be in compliance with the 115% or the 120% TDG levels during the fish migration seasons. Each exceedance is then evaluated to see if any of 12 factors contributed to the occurrence of the exceedance. Changes in spill are then made, daily if necessary, to correct spill to 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. BiOp Guidance, Table 9.6-3 (on Page 9-89) Estimated spill levels and gas caps for FCRPS projects during spring (all) and summer (non-transport) projects.

    a. Limiting Factors: gas cap, % of river flow (JDA-60% at night, TDA 40% of instantaneous flow), and minimum spill at BON of 75 kcfs.

2. Oregon Waiver and Washington Rule Modification (115% forebay, 120% tailwater)

    a. Corps Check Spill Program (graphic) reviewed daily; calculate high 12-hour daily average. 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. 2002 Spill Log

    c. Daily High-12 hour TDG level reported to TMT every two weeks.
        1. TMT Webpage at www.nwd-wc.usace.army.mil/tmt/
        2. Operations
        3. Spill Charts (example: May 24)
        4. Annual summary

3. Firm Generation Commitments
    a. LWG, LGS, LMN, IHR approximately 11.5 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 for BON (with new deflectors on bays 1-3 and 16-18) 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.
    a. 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
    a. 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)
    b. At flows above 200 kcfs at BON, little degassing occurs between BON and Camas.
    c. 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.

3.9 Spill Patterns

As a general rule, optimal spill patterns for TDG typically tend to be a flat pattern, or equal amounts of spill from each spillbay, across the spillway. Although these conditions may be good for TDG, they may not necessarily be good for ESA listed fish in the affected area. 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 at up to 9 hydroprojects within the system if spillway patterns are not optimized, resulting in an unknown impact 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.

3.10 Power Load Redistribution

Because power generation and spill have different TDG production potential at various dams, 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 because passing water through turbines at Grand Coulee adds little to no gas to the water, full turbine operation at Coulee combined with spill at Chief Joseph could have more TDG benefits system wide rather than both spilling water and generating power at each dam.

3.11 Physical Changes to Hydroprojects

Making physical changes to the hydroprojects typically means constructing more physical structures at the dams. Examples of structural changes to the dams that have either been made or proposed in recent years include spillway flow deflectors, additional spillbays at existing dams, removable spillway weirs, and powerhouse/spillway divider walls.

3.11.1 Flow Deflectors

Spillway flow deflectors have been installed at many dams in the FCRPS (Table 2-2). 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.

3.11.2 Additional Spillway Bays

Building additional spillway bays at existing dams to allow voluntary and involuntary spill releases to be more spread out, 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 (See section 2.9).

3.11.3 Fish Passage Improvement

The BiOp requires that certain performance objectives be met. Currently many agencies prefer the spillway as a non-turbine passage route for fish, despite the generation of higher than preferred levels of TDG. Any 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.

A Removable Spillway Weir (RSW) is an overflow weir that can be installed in a regular spillbay at dams in the FCRPS. The weir is elevated from the typical spillway ogee, thereby creating a surface draw from the forebay rather than the deep draw conditions of most existing spill operations. This device is meant to 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 weir can be lowered out of position down to the river bottom whereby the dam can pass unimpeded the standard project flood flow. RSWs are a means to provide or maintain levels of fish passage while possibly reducing the volume of voluntary spills. It is conceivable that if voluntary spill can be reduced, a corresponding reduction in the production of TDG could also be realized.

Additional measures designed to pass juvenile fish via improved screened bypass or alternatively surface bypass systems at powerhouses may also provide a reduction in TDG. If fish can be successfully passed via a non-turbine route other than spill (e.g. Bonneville 2 Corner Collector), then it may provide an opportunity to reduce the reliance on voluntary spill as a means of juvenile salmon passage and in turn could have a beneficial effect on 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.

3.11.4 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 could 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. Additional investigation is required to increase understanding of this issue prior to pursuit of corrective actions. 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.

This project addresses RPA Action 135, which states: "The Corps shall include evaluations of divider walls at each FCRPS project in the spillway deflector optimization program. Design development and construction of the divider walls would begin only after coordination within the annual planning process, and only if warranted."

3.12 Long Term Implementation Plan

Appendix Table B-3 of the BiOp lists actions that were determined to possibly further CWA objectives but that are not specifically called for in the BiOp RPAs. At the time of publication of the BiOp, these actions were to be considered for implementation in the future. These include development of TMDLs, long-term Gas abatement alternative selection studies including side channel spillways, baffled spillways and/or raised stilling basins.

The states and EPA have completed and are currently working on TMDLs, and the Corps is currently funding the construction of Chief Joseph Flow deflectors to couple with alternative power loading at Grand Coulee to reduce TDG. However, Phase II of the DGAS study, completed in May 2002, evaluated the remaining alternatives and determined:

"*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 indicated on page 69 in the TMDL, "*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*."

Because of these findings, further investigations into these alternatives have not been scheduled.

4 Hydrosystem 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, tables 3-1 through 3-6 demonstrate the current status of the 28 items listed as Phase I and Phase II items in the TMDL.

4.1 Overall Hydrosystem TDG Issues

Although TDG issues throughout the basin can be considered inter-related, certain planned and historic activities and actions can be considered as overall hydrosystem TDG issues. These issues include the DGAS studies (2.4), the BIOP (1.1), water quality monitoring (2.1), and investigating the relationship between TDG and adult salmonid lesions known as headburn.

4.2 Adult Salmonid Headburn

Causes of adult salmonid head burns have been investigated in recent years through radio tracking studies and evaluations conducted by Anadromous Fish Evaluation Program (AFEP) and Fish Passage Operations and Maintenance Coordination Team (FPOM) participants. Studies conducted by the Pacific Northwest National Laboratory (PNNL) (Neitzel et al. 2004) concluded that most head burns are a result of fungal infections of previously sustained injuries, some of which may occur during fallback through spill gates at projects. University of Idaho studies of migrating adult salmon, using depth sensitive radio tags, reported that most adult fish swim below TDG compensation depths as they migrate upriver (Johnson et al. 2005). Thus the connection between high TDG levels and head burn is less direct for adults than juvenile fish. No additional studies are planned.

4.3 Overall Hydrosystem - Recent TDG History and Schedule

Action Item #	Type Of Measure	Project Location	TDG Measures	Status/ Year(s)	TMDL IP Phase	NMFS 2000 BiOp RPA
Systemwide 1	Study	FCRPS	DGAS	1994-2002		
Systemwide 2	Plans	FCRPS	NMFS FCRPS Biological Opinion	2000		
Systemwide 3	Activity	FCRPS	Predator Removal/Abatement	Ongoing	II	
Systemwide 4	Operations	FCRPS	Improved O&M	Ongoing	II	
Systemwide 5	Studies	FCRPS	Turbine Survival Program	Phase I - 2003 Phase II - 2004	II	
Systemwide 6	Model	FCRPS	SYSTDG	Ongoing		
Systemwide 7	Bio Study	FCRPS	Investigate if Adult Head Burn is Caused by High TDG	2001-2004		

Table 4-1 Overall Hydrosystem - Recent TDG History and Schedule

5 Federal Mid-Columbia River

5.1 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.

5.2 Chief Joseph Dam

Chief Joseph Dam currently does not have a means of preventing gas supersaturation under spill conditions. Involuntary spill occurs 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 at Chief Joseph Dam because there is no anadromous fish migration past this project.

The BiOp required the Corps and Reclamation to individually and jointly examine 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, a feasibility level document. The Initial Appraisal Report examined 19 alternatives and recommended nine for further study. The System Configuration Team (SCT) participated in a screening process to reduce the nine alternatives down to three. The preferred alternative was to install flow deflectors at Chief Joseph Dam and to operate it jointly with Grand Coulee. Joint operation would entail a shifting of spill from Grand Coulee to Chief Joseph and a shifting of generation in the opposite direction.

5.3 RPA Action Item 136

The 2000 Biological Opinion RPA Action Item 136 required the Corps to develop and construct spillway deflectors at Chief Joseph Dam by 2004 to minimize total dissolved gas (TDG) levels associated with system spill. Additionally, RPA 136 instructed the Corps, Reclamation, and BPA, to the extent feasible, to operate Grand Coulee and Chief Joseph dams jointly to reduce the incidence of spill and TDG supersaturation below Grand Coulee by spilling proportionately at Chief Joseph and shifting electrical load to Grand Coulee Dam.

5.3.1 Chief Joseph Dam Spillway Deflectors

In April 2000 the Seattle District of the Corps completed a General Reevaluation Report on the Chief Joseph Dam Gas Abatement Study. This study considered eighteen alternatives to reducing TDG contributions from Chief Joseph dam. The preferred alternative was to design and construct spillway deflectors at the project and to operate Chief Joseph jointly with Grand Coulee. Congressional funds requested in FY 2001 were not provided.

The Corps received $500,000 of congressional funds in FY03 to initiate design of the flow deflectors selected during the General Reevaluation Report process as well as complete the design of some pre-construction projects necessary for dam preparation prior to the construction of the flow deflectors. The Corps received an additional $2,000,000 of congressional funds for FY04 to complete design and modeling work associated with the flow deflectors and to initiate a contract for the construction of deflectors. In FY05 the Corps awarded a contract totaling $14.7 Million for deflector construction. Construction of the flow deflectors began in FY06 with an estimated completion date at the end of FY08. One flow deflector has been completed as of October 2006.

5.3.2 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 Implementation Team was also briefed on the WQT.

The study conducted by the WQT concluded that reductions to total dissolved gas (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 are currently being constructed at Chief Joseph Dam and joint operations with Grand Coulee are likely not possible during the construction due to the limited number of spillway bays available at Chief Joseph Dam. Once all deflectors are installed at the end of FY08, joint operations with Grand Coulee will again be a viable alternative to reduce TDG saturations in the Columbia River. A post-deflector spill test will be conducted at Chief Joseph Dam to determine the TDG exchange properties during spillway discharges with flow deflectors. 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.

5.3.1 Federal Mid-Columbia History and Schedule

Table 5-1 Federal Mid-Columbia History and Schedule

Action Item #	Type Of Measure	Project Location	TDG Measures	Status/ Year(s)	TMDL IP Phase	NMFS 2000 BiOp RPA
Fed Mid-C - 1	Operational	Grand Coulee	Shift spill to Chief Joseph Dam	2004		
Fed Mid-C - 2	Physical	Grand Coulee	Submerge spill by extending outlet tubes	?		
Fed Mid-C - 3	Studies	Chief Joseph	Physical Model Built	1999		
Fed Mid-C - 4	Studies	Chief Joseph	Flow Deflector Models Tested	2000		
Fed Mid-C - 5	Operational	Chief Joseph	Shift power generation to Grand Coulee Dam	2004		
Fed Mid-C - 6	Physical	Chief Joseph	Flow Deflectors	2005-2008	I	

5.4 Non-Federal Mid-Columbia Projects

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.

5.5 <u>Snake River – Hells Canyon</u>

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. 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 Idaho Department of Environmental Quality (IDEQ) and Oregon Department of Environmental Quality (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).

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 U.S. Army Corps of Engineers (COE) 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. Measured levels in the spill of Brownlee Dam reached 128% of saturation with little dissipation downstream through Oxbow Reservoir. At spill rates over about 3000 cubic feet per second (cfs), TDG levels in spilled water consistently exceeded the 110% of saturation criterion. It should be noted that TDG was measured immediately 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.

A TDG adaptive management plan is being developed through the section 401 certification process and includes protection, mitigation, and enhancement (PME) 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, and 3) Brownlee Dam spillway flow deflectors. The management plan is designed to be adaptive and a monitoring plan will be developed. Measures at Oxbow Dam may be included based on adaptive elements of the TDG management plan. The schedule for the adaptive plan is in development.

5.5.1 Partial History of Hells Canyon TDG Events

Table 5-2 Partial History of Hells Canyon TDG Events

Action Item #	Type Of Measure	Project Location	TDG Measures	Status/ Year(s)	TMDL IP Phase	NMFS 2000 BiOp RPA
Hells-C - 1	Study	Brownlee	TDG Monitoring	1997, 1998, 2006		
Hells-C - 2	Study	Oxbow	TDG Monitoring	1997, 1998, 2006		
Hells-C - 3	Study	Hells Canyon	TDG Monitoring	1997, 1998, 1999, 2006		
Hells-C - 4	Study	Hells Canyon	Flow Deflectors	2000		
Hells-C - 5	Study	Brownlee	Flow Deflectors	2005		

5.6 Lower Snake River

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

5.6.1 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. RSW flow plus minimum training flows has the potential to significantly reduce TDG levels over current spill operations while providing benefits to juvenile fish migration. To date, near field TDG testing has been delayed to avoid interferences with ongoing fish passage research on the RSW and surface collection prototypes at Lower Granite.

Another TDG task includes constructing and testing 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.

Operational changes (spill patterns) will also be examined for potential TDG reduction benefits. 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.

5.6.2 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.

During FY02, testing of a spillway sectional model was completed along with construction of a general physical hydraulic model of Little Goose dam. Testing of the general model began in FY02 and was planned to continue into FY03. Because of the lack of funds and low SCT priority ranking, this project was suspended and is not currently funded. The model testing was to include the examination of a spillway/powerhouse divider wall as well as tailrace hydraulic conditions to allow development of spill patterns to achieve acceptable tailrace hydraulic conditions for both adult fish passage and juvenile fish egress from the tailrace area. Little Goose tailrace can present poor conditions for juvenile egress and adult fish passage. In addition to consideration of altered spill patterns to reduce TDG, the Walla Walla District is currently designing an RSW targeted for installation at Little Goose in the spring of 2009. RSW flow plus minimum training flows has the potential to significantly reduce TDG levels over current spill operations while providing benefits to juvenile fish migration. In addition, a powerhouse/spillway divider wall would provide reductions in TDG loading to downstream water bodies during spillway operations.

Once testing is complete, design of deflectors will be initiated along with required NEPA documents. Possible modifications include the addition of deflectors in end bays 1 and 8. If Bay 1 is chosen for RSW installation, a deflector that is both fish friendly and that provides benefits for the reduction of TDG will be installed in conjunction with the RSW. Consideration may also be given to relocating the deflectors at an elevation optimized for current operation. Deflector improvements would provide benefits in reduced TDG during involuntary spill events. A contract for installation of end-bay deflectors is anticipated to occur in FY2006. Additionally, divider walls may be constructed to further improve TDG by reducing powerhouse flow entrainment into the spill waters. Following the installation of the deflectors, a post construction TDG near field test will be completed in April or May 2007.

5.6.3 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.

A removable spillway weir is currently under construction for Lower Monumental Dam and is scheduled to be in place for the 2007 fish passage season. RSW flow plus minimum training flows has the potential to reduce TDG levels over current spill operations while providing benefits to juvenile fish migration.

5.6.4 <u>Ice Harbor Dam</u>

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. Continuing work will include biological studies to determine fish survival over the spillway. A removable spillway weir 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 spill operations while providing benefits to juvenile fish migration.

5.6.5 <u>Lower Snake River History and Schedule</u>

(Table for this section is on the following page)

5.7 <u>Clearwater River</u>

5.7.1 <u>Dworshak Dam</u>

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 a US Fish and Wildlife fish hatchery (Dworshak 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.

Table 5-3 Lower Snake River History and Schedule

Action Item #	Type Of Measure	Project Location	TDG Measures	Status/ Year(s)	TMDL IP Phase	NMFS 2000 BiOp RPA
Lower Snake 1	Bio Study Physical – Operational	Lower Granite	Surface Bypass Collection	1995 – 2000		
Lower Snake 2	Study – Physical – Operational	Lower Granite	Gas Fast Track	Not funded due to low priority ranking by SCT		
Lower Snake 3	Study	Lower Granite	Sectional Hydraulic Model	TBD		
Lower Snake 4	Physical	Lower Granite	Optimize Deflectors	TBD		
Lower Snake 5	Study	Lower Granite	New Spill Patterns	2003-2006 Final TBD in conjunction with RSW operations.		
Lower Snake 6	Physical	Lower Granite	Pier Nose Extensions	TBD		
Lower Snake 7	Physical	Lower Granite	Divider Walls	TBD		
Lower Snake 8	Physical – Bio Study	Lower Granite	RSW	2002 – 2007	I	
Lower Snake 9	Bio Study	Lower Granite	Spillway Passage Survival Study	2003 – 2006	I - II	
Lower Snake 10	Gas Study	Lower Granite	Near Field Testing	2003?		
Lower Snake 11	Study – Physical - Operational	Little Goose	Gas Fast Track	2002 – TBD: Not funded due to low priority ranking by SCT		
Lower Snake 12	Study	Little Goose	General Model Tests	TBD		
Lower Snake 13	Operational	Little Goose	New Spill Patterns	Final Patterns TBD after RSW installation. 2005-2006 Interim patterns developed to support RSW design		
Lower Snake 14	Study -Physical Operational	Little Goose	End Bay Deflectors	TBD	I	
Lower Snake 15	Study - Physical Operational	Little Goose	Optimize Deflectors	TBD		
Lower Snake 16	Study -Physical Operational	Little Goose	Spillway Divider Wall	TBD		
Lower Snake 17	Study - Physical Operational	Little Goose	Spillway Sectional Model Test	2002 – TBD: Not funded due to low priority by SCT		
Lower Snake 18	Bio Study	Little Goose	Spill Passage Survival Studies	2004 – 2006	I - II	
Lower Snake 19	Gas Test	Little Goose	Near Field Test	TBD		
Lower Snake 20	Physical – Bio Study	Little Goose	RSW	2009 – 2012: Currently under design with installation targeted for 2009	II	
Lower Snake 21	Study	Lower Monumental	Physical Model Development	1999		
Lower Snake 22	Physical	Lower Monumental	Gas Fast track	2001 - 2004		
Lower Snake 23	Physical	Lower Monumental	End Bay deflectors	2001 – 2003	I	
Lower Snake 24	Operational	Lower Monumental	Spill patterns	Final patterns TBD after RSW installation. Interim patterns 2002 - 2006		
Lower Snake 25	Physical	Lower Monumental	Divider Wall Report	2004		

Table 5-3 Lower Snake River History and Schedule (Continued)

Action Item #	Type Of Measure	Project Location	TDG Measures	Status/ Year(s)	TMDL IP Phase	NMFS 2000 BiOp RPA
Lower Snake 26	Physical	Lower Monumental	- Report on Juvenile Bypass Outfall Reloc.	2004	I	
Lower Snake 27	Physical	Lower Monumental	- Stilling Basin Repair	2001 – 2003		
Lower Snake 28	Gas Study	Lower Monumental	Near Field Test	2004		
Lower Snake 29	Bio Study	Lower Monumental	Passage/Survival	2003-2006	I - II	
Lower Snake 30	Study	Lower Monumental	Extended Fish Screens	TBD	II	
Lower Snake 31	Physical – Bio Study	Lower Monumental	RSW	2007 – 2010 Currently under construction with installation targeted for 2007	II	
Lower Snake 32	Physical	Ice Harbor	Flow Deflectors (4)	1996	I	
Lower Snake 33	Physical	Ice Harbor	Flow Deflectors (4)	1997	I	
Lower Snake 34	Physical	Ice Harbor	Flow Deflectors (2)	1999	I	
Lower Snake 35	Gas Study	Ice Harbor	Near Field Test	Not Scheduled		
Lower Snake 36	Operational	Ice Harbor	Spill Patterns	1999 – 2006 Final Patterns TBD in conjunction with RSW operations		
Lower Snake 37	Bio Study	Ice Harbor	Passage/Survival	1999 – 2005	I - II	
Lower Snake 38	Physical – Bio Study – Operat.	Ice Harbor	RSW	2003 – 2008	II	
Lower Snake 39	Phys. – Study	Ice Harbor	Divider Wall	TBD		

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.

5.7.2 Clearwater River History and Schedule

Table 5-4 Clearwater River History and Schedule

Action Item #	Type Of Measure	Project Location	TDG Measures	Status/ Year(s)	TMDL IP Phase	NMFS 2000 BiOp RPA
Clearwater 1	Study	Dworshak	Identify potential methods of reducing production of TDG.	TBD – Not Currently Funded		139
Clearwater 2	Physical	Dworshak	Modifications as recommended by TDG study. Modifications may include spillway modifications, Turbine Installation etc.	TBD Based on Clearwater 1		139
Clearwater 3	Physical	Dworshak	Spillway Modifications	TBD		139
Clearwater 4	Physical	Dworshak	Turbine Installation	TBD		139
Clearwater 5	Study	Dworshak	Hydrologic Analysis	TBD		139
Clearwater 6	Study	Dworshak	Model Construction	TBD		139

5.8 Lower Columbia River

5.8.1 McNary Dam

The McNary spillway consists of 22 spillway bays, all of which have flow deflectors. All bays were outfitted with hoists in 2002 that allow for previously impossible, relatively instantaneous modifications to spill patterns. 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. New spill schedules to be implemented in 2003 are expected to resolve this pattern 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.

Currently, McNary Dam is being studied for turbine replacement. The 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 (used to operate two spillway gates) was also operating in an overload condition. 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. The contract was written with an option to complete rehabilitation of up to four additional gates depending on the availability of O&M funds. Gates to be rehabilitated will be 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.

The gate hoists for the remaining sixteen gates also need to be evaluated to determine if past operation in overload conditions has stressed any components to generate concerns which require modifications be performed. The evaluation will also consider the loads from the rehabilitated gates and will determine if re-rating the hoists is possible to meet the actual load conditions or determine what modifications are necessary to allow the re-rating of the hoist. Evaluation of these hoists is dependent on the availability 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 are currently being rehabilitated under Contract DACW68-06-C-0029. Until such time as all of these actions 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.

5.8.2 <u>John Day Dam</u>

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. The additional increment of improvement in gas entrainment during involuntary spill conditions prompted reconsideration of deflector installation on the end bays. Also under consideration is an extended flow deflector on Bay 20, which would potentially be installed in association with an RSW prototype for testing at that bay. The RSW prototype program at John Day has been deferred to address potential adverse effects of its operation on juvenile fish egress from the stilling basin. Evaluations have resumed and, subject to results from the testing of temporary spillway weirs at McNary Dam in 2007, a program to test RSWs at John Day will resume with prototype tests tentatively beginning in 2008.

5.8.3 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 significantly 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.

5.8.4 Bonneville Dam

Deflectors were constructed on 13 of the 18 spillbays in the early 1970s at Bonneville Dam. These deflectors were designed for involuntary spillway releases, however, because of the shift from involuntary to voluntary spill for fish passage, TDG supersaturation during spillway operation has again become a regional concern.

Deflector construction in bays 1, 2, 3, 16, 17, and 18 was completed in 2002. A second post-construction evaluation (biological) test planned for the spring and late summer of 2003 was deferred due to funding priorities. These deflectors were installed about seven feet lower than where the existing deflectors are located. Revised spill patterns were established for the new configuration and near field TDG testing to determine effectiveness of the new flow deflectors was conducted. Additional testing is currently planned for 2007, to look at passage survival through the spillway, looking at the alternative deflectors, as well as spill gate openings, and patterns to determine whether survival can be improved to help determine if modifications to the existing deflectors are warranted.

5.9 Lower Columbia River History and Schedule

Table 5-5 Lower Columbia River History and Schedule

Action Item #	Type Of Measure	Project Location	TDG Measures	Status/ Year(s)	TMDL IP Phase	NMFS 2000 BiOp RPA
L Columbia 1	Document	System	Final TMDL-TDG	2002		
L Columbia 2	Physical – Operational – Study	McNary	Gas Fast Track	2002 – TBD Not funded due to low priority ranking by SCT		
L Columbia 3	Physical – Operational – Study	McNary	Gate Hoists	2002 - Unresolved		
L Columbia 4	Physical – Operational – Study	McNary	Deflector Optimization	2002		

L Columbia 5	Physical – Operational – Study	McNary	Spill Patterns	2002		
L Columbia 6	Physical – Operational – Study	McNary	Divider Walls	TBD		
L Columbia 7	Physical – Operational – Study	McNary	Training Walls	TBD		
L Columbia 8	Physical – Operational – Study	McNary	Modeling	TBD		
L Columbia 9	Physical – Operational – Study	McNary	Outfall relocation	TBD	II	
L Columbia 10	Physical – Bio Study	McNary	RSW or other Surface Passage measures	2005 - 2012		

Table 5-5 Lower Columbia River History and Schedule (Continued)

Action Item #	Type Of Measure	Project Location	TDG Measures	Status/ Year(s)	TMDL IP Phase	NMFS 2000 BiOp RPA
L Columbia 11	Physical	McNary	Turbine Replacement	2008-2015		
L Columbia 12	Bio Study	McNary	Spillway Passage Survival	2003 - 2006	I - II	
L Columbia 13	Study	McNary	Near Field Test	Not Scheduled		
L Columbia 14	Physical	McNary	Endbay Deflectors	2002	I	
L Columbia 15	Physical	John Day	Flow Deflectors (18/20)	1998 – 1999	I	
L Columbia 16	Study - Physical	John Day	RSW (Surface Bypass)	Ongoing	II	
L Columbia 17	Bio Study	John Day	Passage/Survival Studies	2000-2004	I - II	
L Columbia 18	Physical	John Day	Extended Screens	2004 Decision	II	
L Columbia 19	Physical	John Day	End Bay Deflectors	TBD	I	
L Columbia 20	Physical	John Day	End Bay Deflector – Bay 1	TBD	I	
L Columbia 21	Study – Physical	The Dalles	Spillway Improvement Study	2003 – 2008	I	
L Columbia 22	Study – Physical	The Dalles	Spill Wall	2004		
L Columbia 23	Study – Physical	The Dalles	Forebay Guidance	Ongoing		
L Columbia 24	Study – Physical	The Dalles	Spillbay and Tailrace Modifications	Ongoing		
L Columbia 25	Study - Physical –	The Dalles	Surface Bypass	2003 – 2007 (On hold)		
L Columbia 26	Study – Physical	The Dalles	Turbine Intake Blocks	2000-2002 Terminated	I	

L Columbia 27	Study – Physical	The Dalles	Sluiceway Outfall relocation	2000-? On Hold	I	
L Columbia 28	Bio Study	The Dalles	Spillway and Sluiceway Survival Study	2000 – 2009	I - II	
L Columbia 29	Physical	Bonneville	Spillway Deflectors (13/18)	1970’s		
L Columbia 30	Physical	Bonneville	Spillway Deflectors (18/18)	2002	I	
L Columbia 31	Study - Physical	Bonneville	PH1 improvements	Terminated	I	
L Columbia 32	Study – Physical	Bonneville	PH1 Surface Bypass	Ongoing	I	
L Columbia 33	Physical	Bonneville	PH2 Corner Collector	2004	I	
L Columbia 34	Physical Study	Bonneville	Turbine Improvements (MGRs)	Ongoing	II	
L Columbia 35	Physical	Bonneville	PH2 FGE Improvement	Underway	I	
L Columbia 36	Bio Study	Bonneville	Passage/Survival Studies	Ongoing	I - II	

Table 5-5 Lower Columbia River History and Schedule (Continued)

Action Item #	Type Of Measure	Project Location	TDG Measures	Status/ Year(s)	TMDL IP Phase	NMFS 2000 BiOp RPA
L Columbia 37	Study – Physical – Operational	Bonneville	Gas Fast Track	2002		
L Columbia 38	Study	Bonneville	Near Field Testing	2002		
L Columbia 39	Physical	Bonneville	Improve Existing Deflectors if needed	Ongoing		
L Columbia 40	Operational	Bonneville	Spill Patterns	Ongoing		

6 Long Term Plan

Section 3 presents in detail what is described in the lower Columbia River TMDL as the short-term and long-term plans for TDG abatement, indicated as the Phase I and Phase II in the TMDL IP, all of which need to be addressed by 2020. However the Corps recognizes 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. Other items that were discussed in the DGAS study that may need to be revisited after the Phase I and Phase II implementation actions have been completed.

Implementation of operational alternatives, additional or modified spillway flow deflectors, and powerhouse/ spillway flow separation walls has the potential to significantly reduce production of TDG and can be implemented in the near term.

Other alternatives are considered more long term since 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

7 RPAs Addressed

The 2000 BiOp contains 199 Reasonable and Prudent Alternatives that the Action Agencies are attempting to meet in an effort to avoid jeopardy to ESA listed anadromous salmonids. These include items ranging from habitat work in headwater streams to fish passage improvement devices at the Federal hydroelectric projects. The following table represents a partial list of the reasonable and prudent alternatives related to TDG that were identified in the BiOp. Those RPAs that are directly related to TDG are in the table, however, those with less direct ties (e.g. extended fish screens, etc…) are only partially covered.

As of December 3, 2002, the Corps believes that all of the BiOp RPAs noted in this table are either in the process of being addressed, or have been addressed in an attempt to fulfill the requirements of the BiOp. (Please Refer to the BiOp Implementation Plan). Appendix C has a more detailed list of the RPAs addressed in table 7-1.

Table 7-1 TDG Reasonable and Prudent Alternatives

Actions		Reasonable and Prudent Alternative						
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

8 Conclusions

This document is meant to serve two purposes: (1) address part of the plans requested through Appendix B of the 2000 NMFS FCRPS Biological Opinion; and (2) address needs of the States of Oregon and Washington to adjust the water quality criterion of 110% TDG upward to allow for greater volumes of spill to pass juvenile salmonids and conduct tests. In this document, the Corps has presented the background of TDG issues in the Columbia River Basin, the rationale for preparing the document, what can be and has been done to address TDG issues, and what the Corps' planned schedule is for addressing these issues. Much of the background information was taken from documents found in the citations, from assisting government agencies, or gathered from personnel in the Northwestern Division or Portland, Seattle or Walla Walla District, Corps of Engineers. This document was not meant to be all-inclusive, in that the complete history of TDG issues in the Columbia Basin could make for an unwieldy document and could overwhelm the reader, rather, it was meant to provide a background of TDG Issues and how the Corps has dealt and is attempting to deal with them.

Mainstem Snake and Columbia River Water Temperature

9 Introduction

Appendix B of the NMFS 2000 BiOp called for a plan to outline the structural and operational changes to the current river system that could be used to improve the overall water quality in these rivers. The long-term goal of the plan was to improve water quality but also to conserve threatened and endangered species, thus meeting the requirements of both the Clean Water Act (CWA) and the Endangered Species Act (ESA). The 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.

Although TDG has been the primary water quality parameter monitored by the Corps, water temperature is also measured because it affects TDG saturation levels, and because it can adversely impact the health of fish and other aquatic organisms. Both TDG and water temperature are closely linked to water management operations (e.g. water released over the dam spillways, releases through the powerhouses and other facilities, and forebay and tailwater water surface elevations) at Corps projects.

This water temperature document presents the background of water temperature issues in the Columbia River Basin, the rationale for preparing the document, what is being done and what has been proposed to address and resolve water temperature issues. This document is composed of five major categories including:

1) The background of water temperature issues in the Columbia and Snake rivers, the goal of the NMFS 2000 FCRPS BiOp and the Total Maximum Daily Load process,
2) The monitoring of water temperature in the area covered by the plan,
3) A brief discussion addressing the Reasonable and Prudent Alternative actions in the BiOp that address water temperature and the long-term non-BiOp (Clean Water Act) strategy to get temperature levels below 20°C.
4) A description of operational, structural and other changes that have been proposed that may have potential to lower water temperature levels or provide a better understanding of water temperature impacts to aquatic species.
5) A final summary and appendix.

9.1 Background

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). The hypothesis being that Snake River juvenile fall Chinook outmigration timing is delayed by cooler-than-historical water temperatures during incubation and early rearing life stages due to the modified releases from Dworshak Dam.

The geographic scope of this water quality plan, as outlined in the BiOp, will include the Columbia River from the international boundary, the Clearwater River from Dworshak Dam downstream to the Snake River, and Brownlee Dam on the Snake River, to the tailrace of Bonneville Dam. This plan will also briefly address issues above the international boundary as items to be considered for the Clean Water Act, that were not necessarily called for in the BiOp. There are three primary storage reservoirs in the United States, Grand Coulee Dam, Brownlee Dam and Dworshak Dam. Two major storage projects also exist in Canada including Mica and Keenleyside dams. Six run of the river dams exist on the middle and Lower Snake river, four on the Lower Columbia and six on the middle Columbia.

9.2 <u>2000 FCRPS Biological Opinions</u>

The NMFS and FWS 2000 Biological Opinions (BiOp) for operations of the FCRPS state: "The two agencies intend the recommendations and requirements of these opinions to be mutually consistent. They represent the Federal biological resource agencies' recommendations of measures that are most likely to ensure the survival and recovery of all listed species that are within the current authorities of the Action agencies."

In developing the NMFS BiOp, however, the goal was also to consider the respective ecological objectives of both the CWA and ESA. In many instances, the goals of the two acts are mutually inclusive in that many of the benefits of appropriate levels of dissolved gas and temperature can be realized by the endangered species within the system. However, despite the overlap, there may be actions that help to meet the CWA that have detrimental, little, or no effect on endangered fish species.

There are 11 RPA actions directly addressing water temperature in the NMFS 2000 BiOp. Specifically, RPAs 19, 20, 33, 34, 35, 114, 115, 141, 142, 143 include direct language regarding biological studies, the collection of temperature data, and/or the reduction of water temperatures within the FCRPS.

Appendix B of the 2000 NMFS BiOp, is meant to address conservation measure actions in the mainstem Columbia River that go beyond the ESA RPA recommendations. The Appendix B geographic scope for temperature ranges in 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. In Appendix B, NMFS indicates that their long-term goal for water temperature is standard attainment in all critical habitats in the Columbia and Snake River basins (For detailed information on individual states mainstem water temperature standards, please see BiOp Appendix B).

9.3 <u>Water Quality Team</u>

It is important for EPA, NMFS, USFWS, the States, Tribes and the Federal Action Agencies to understand the relationship between the Plan and ongoing TMDL planning processes, particularly their relationship with each other and evaluation and implementation of the system improvements and studies. Therefore, final development and implementation of the Plan could be accomplished through reformulation of the Water Quality Team, consisting of senior policy analysts and supported by technical staff from Federal agencies (EPA, NMFS, USFWS, Corps, BPA, and Reclamation); the states of Oregon, Washington, and Idaho; Columbia River Tribal governments; and non-Federal entities such as municipalities and PUDs.

The team could also have specific TDG and temperature technical subcommittees included under the overall umbrella of team actions. The new Water Quality Team could also be a cross-connecting link between the NMFS Regional Implementation Forum and the Columbia River Basin Forum, as appropriate, through input and updates on water quality plan implementation. The new Water Quality Team would review the water quality plan developed by the Action Agencies to help identify key TDG and temperature studies and implementation of structural and operational changes to the FCRPS system, including PUDs. The plan's timeline would provide specific milestones to conclude discussions on technical issues related to structural and operational changes to the FCRPS, consultation with the other basin forums discussed above, and implementation of actions so that they may be considered in conjunction with the 2005 mid-point evaluation under the RPA.

The BiOp goes on to state:

"To ensure progress toward the long-term goal, the Corps, BOR (Reclamation), and BPA will also work with NMFS, USFWS, EPA, the Columbia River Tribes, and the states of Washington, Oregon, Idaho, and Montana through an adaptive management process as a part of the water quality plan to achieve the following:

- Make operational and capital investment decisions at the FCRPS projects to move toward attainment of thermal water quality standards.
- Seek consensus on offsite mitigation measures that would contribute to attainment of water temperature standards.
- Fund, implement, and report on adequate physical and biological temperature monitoring to assess compliance with state and Tribal water quality standards and other special conditions that may apply.
- Cooperate with others to fund implementation and modeling to better assess and act on thermal water quality problems and opportunities.
- Develop emergency measures that may be needed to address immediate and acute water temperature problems affecting listed salmon.

The feasibility of meeting the long-term goal will be revisited annually during the water quality improvement planning process."

9.4 Mainstem Water Quality Plan Workgroup

The 2000 Biological Opinion observed the complementary features of the ESA and the CWA. It was recognized that an assertive implementation 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 NOAA

Fisheries, EPA, USFWS and the Action Agencies called for the integration the Biological Opinion water quality actions with the relevant objectives of the CWA and other fish and wildlife and water quality statutes. The mechanism by which this integration could occur was through the development of a mainstem water quality plan.

The Biological Opinion Section 9.6.1.7 and Appendix B charted a course for the development of a comprehensive Columbia and Snake River water quality plan. From the outset of the planning effort it was clear that the scope of the mainstem plan would be broader than the RPAs and would include additional actions to improve mainstem water quality by reducing total dissolved gas and water temperature. Appendix B of the Biological Opinion tabulated actions required to avoid jeopardy as well as those actions that are beyond the scope of the RPAs. However, although Appendix B is not itself a water quality plan it does suggest the procedure for the development of a plan toward attainment of water quality standards in the Federal Columbia River Power System. Furthermore, it was anticipated that a mainstem water quality plan would include Columbia and Snake river TMDL limits currently under development by the states, tribes and EPA.

To this end a Mainstem Water Quality Plan Workgroup (Workgroup) was formed in 2001 and has been meeting on an as needed basis since. It has included participation by these entities:

Bonneville Power Administration
Bureau of Reclamation
Chelan County PUD
Douglas County PUD
Environmental Protection Agency
Fish Passage Center
Grant County PUD
Idaho DEQ
Idaho Power Company
Nez Perce Tribe
NOAA Fisheries
Oregon DEQ
Pacific Northwest National Laboratory
U.S. Army Corps of Engineers
U.S. Fish and Wildlife Service
Washington DOE

The Workgroup has 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 Federal Columbia River Power System, 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 total dissolved gas 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.

Simultaneous to the early meetings of the Workgroup and the drafting of the above statements, the Northwest Power Planning Council (now Northwest Power and Conservation Council) conducted a solicitation for projects implementing the Mainstem Provincial Review. The Workgroup reviewed the water quality projects responding to the solicitation and offered policy guidance regarding the proposals to the Power Council and the Columbia Basin Fish and Wildlife Authority. Recently, the Workgroup has focused attention on the drafting of the Mainstem Water Quality Plan and commenting on updates of the Plan.

9.5 Water Quality Team

The Mainstem Water Quality Plan Workgroup may have specific technical issues arise as they pursue regional water quality planning and policies. Examples of technical issues could include but would not be limited to total dissolved gas or water temperature improvement topics, research needs or designs, monitoring strategies, or TMDL compliance concerns. In these instances the existing NOAA Fisheries technical Water Quality Team operating in support of the Biological Implementation may be called on for assistance. The Workgroup could also communicate with the other technical teams serving the NOAA Fisheries and the regional Implementation Team. These teams include the System Configuration Team and the Technical Management Team regarding issues of Federal Columbia River Power System modification and operation, respectively.

The Water Quality Plan Workgroup was formed to work towards identifying short-term actions for funding and implementation while working towards a comprehensive, long-term Water Quality Plan for the mainstem. This plan is meant to coordinate water quality improvement actions of the 2000 FCRPS Biological Opinion, the Northwest Power and Conservation Council's sub-basin plans, the Clean Water Act, and Tribal treaty and trust resources to benefit fish.

The principle goals for this Plan include:

1) Provide an Implementation Plan for water quality actions as called for in Appendix B of the NMFS 2000 FCRPS BiOp.
2) Serve as an implementation framework for the Columbia/Snake mainstem TMDL
3) Serve as the implementation framework for TDG waivers for the Corps
4) Full engagement of the Columbia River Action Agencies
5) Commitment to ongoing Federal Executives Dialogue

6) Commitment to use unified and best available science, and
7) Commitment to Fund the Plan development

9.6 Total Maximum Daily Loads (TMDLs)

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 obligatory once a water is identified as impaired, i.e. not meeting WQS. TMDLs are typically developed by States or tribes and approved through the EPA. However, EPA may also develop a TMDL.

TMDL Implementation Plans are developed by States to achieve the load allocations identified in the TMDL. Implementation actions include the NPDES Permit Program, State Water Quality Certification Programs, State Non-point Source Management Programs and other mechanisms. The implementation plan development and implementation are the responsibility of the states of Idaho, Oregon and Washington in coordination with Columbia Basin Tribes with implementation by dam operators. However, these states will rely heavily on the Federal Agencies that administer and operate the FCRPS. 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.

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 also (WQS have been adopted by the Tribe but not yet approved by EPA).

9.7 Existing Temperature TMDLs

There are currently no approved temperature TMDLs for the mainstem lower Snake and Columbia rivers.

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 Oregon Department of Environmental Quality (ODEQ), with participation by the US

Environmental Protection Agency (US 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

9.7.1 Anticipated Temperature TMDLs

EPA released a preliminary draft TMDL for water temperature in portions of the Columbia and Snake rivers in September of 2002. This TMDL has not been either re-released as a draft or finalized; a completion time is not known. The Preliminary Draft TMDL addresses 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 have been held since July 2001, in part to discuss the methodology for allocations and potential solutions.

A workgroup was formed to develop the Temperature and TDG TMDLs. This workgroup consisted of staff from the Idaho Department of Environmental Quality, the Oregon Department of Environmental Quality, the Washington Department of Ecology and the EPA. A number of Columbia Basin Tribes, PUDs, Bonneville Power Administration, Corps of Engineers, Bureau of Reclamation, pulp and paper industries, NOAA Fisheries and US Fish and Wildlife Service also participated on the committee. EPA will issue the TMDLs for the parts of the rivers that are in Tribal Reservations.

9.8 Water Temperature and The Corps of Engineers

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 February 1996 (Corps 1996). The Corps policy is to comply with 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.

The Corps and Reclamation recommend coordinating with 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, and 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.

9.9 Water Temperature and The Columbia River Basin States and Tribes

In addition to parts of British Columbia, the Columbia River Basin encompasses parts of Idaho, Oregon, Washington, Montana, Nevada, Utah and Wyoming, each of which has 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, as well as the regional tribes. Although some of these entities have water quality standards, currently EPA has promulgated only the plans the states of Idaho, Oregon and Washington and the Colville Tribe.

9.9.1 Idaho Water Quality 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:

1) Cold water (COLD): 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).

2) Salmonid spawning (SS): 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.

9.9.2 Oregon Water Quality Standards

OAR 340-041-0028

Temperature

(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.

9.9.3 Washington Water Quality Standards

The standards below are the 1997 Washington WQS for temperature. WDOE expects to issue new standards soon. The next update of this Plan will incorporate the new State WQS if they are finalized.

For the Washington water quality standards, the designation of Class A (excellent) waters is as follows. "Temperature shall not exceed 18.0º C (64.4ºF) (freshwater) or 16.0º C (marine water) due to human activity. When natural conditions exceed 18.0º C (64.4ºF) (freshwater) and 16.0º (marine water), no temperature increases will be allowed which will raise the receiving water temperature by greater than 0.3º C.

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 Class A with a special condition. The temperature shall not exceed 20.0º C (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) 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 20.0º C (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 t=34/(T+9)[between 1.13º and 0.9 ºF].

The Snake River from the mouth (confluence with the Columbia River) to the Washington-Idaho-Oregon border (river mile 176.1) is designated Class A with a special condition.

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

9.9.4 Colville Tribal Water Quality 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.

9.10 Snake and Columbia Water Temperatures – A Corps of Engineers Perspective

The Corps believes that water temperatures in the Snake and Columbia mainstem rivers regularly exceeded 20°C prior to impoundment, but also believes that temperatures 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

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

10 Monitoring/Modeling/Operations/Structures

10.1 Physical Monitoring

The Corps Plan of Action for TDG monitoring for 2007 (including temperature) can be found on the TMT website at:
http://www.nwd-wc.usace.army.mil/tmt/wq/tdg_monitoring/2007_final.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 2007 water quality monitoring plan are in Appendix 4 of the annual Water Management Plan.

10.2 Purpose of Water Quality Monitors

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 total dissolved gas.

10.3 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 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.

11 RPAs Addressed

The 2000 BiOp contained 199 Reasonable and Prudent Alternatives that the Action Agencies are attempting to meet in an effort to avoid jeopardy to ESA listed anadromous salmonids. These include items ranging from habitat work in headwater streams to fish passage improvement devices at the Federal hydroelectric projects. Table 11-1 represents a partial list of the reasonable and prudent alternatives related to water temperatures that were identified in the BiOp.

Table 11-1 RPA actions being addressed by this Water Quality Plan

Type of Measures	Reasonable and Prudent Alternative				
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 RPAs noted in this table are either in the process of being addressed, or have been addressed in an attempt to fulfill the requirements of the BiOp. (Please Refer to the BiOp Implementation Plan). Appendix B contains a more detailed list of the RPAs addressed in this table.

11.1 RPA Measure 141

This RPA 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 RPA 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 have been monitoring summer migrants, the susceptibility of these fish to disease, and the link between temperature and migrant mortality. It is anticipated that, in coordination with RPA 143, these data will be combined with GIS and numerical modeling efforts (e.g., RPA

143) to produce a comprehensive assessment of long-term survival in relation to water temperature.

11.2 RPA Measure 143

One of the action items identified within the 2000 BiOp was measure number 143 which stated: "The Action Agencies shall develop and coordinate with NMFS and EPA on a plan to model the water temperature effects of alternative Snake River operations. The modeling plan shall include a temperature data collection strategy developed in consultation with EPA, NMFS and state and Tribal water-quality agencies. The data collection strategy shall be sufficient to develop and operate the model and to document the effects of project operations." The geographic scope of measure 143 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.

In the Water Temperature Modeling and Data Collection Plan for the Lower Snake River Basin, dated October 9, 2003, the RPA 143 technical team recommended to the regional 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 11-2 Model development for RPA measure 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 were 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 Technical Management Team (TMT) and WQT, subsequently defined and identified preliminary model runs required to answer questions originally posed by the team.

Scheduling of this work 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
- Revise data collection as needed to support Phase 3 and other model inputs and improvements

FY2007

- Implementation at Walla Walla District and NWD
- Model optimization

12 Proposed Columbia River Basin Water Temperature Measures

The following tables are a list of actions that have been proposed for 1) reducing overall river temperature, 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 of Engineers, the Bureau of Reclamation and the Environmental Protection Agency. 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.

13 Proposed Mainstem Temperature Reduction Measures

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

13.1.1 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 in an attempt 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 at the request of the National Marine Fisheries Service.

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 4 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 5 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 6 demonstrating the period when Lower Granite was built to the Dworshak flow augmentation measures commencing.

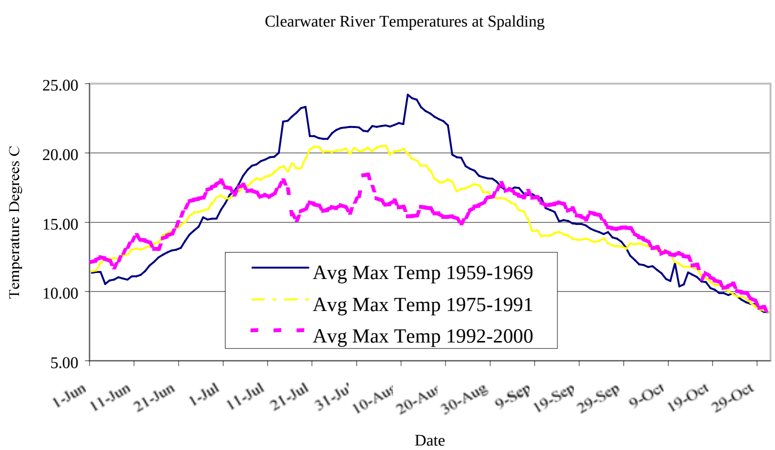

Figure 4. Clearwater average maximum daily temperatures as measured at USGS Gage at Spalding, Idaho from 1959-1969 and 1975-2000.

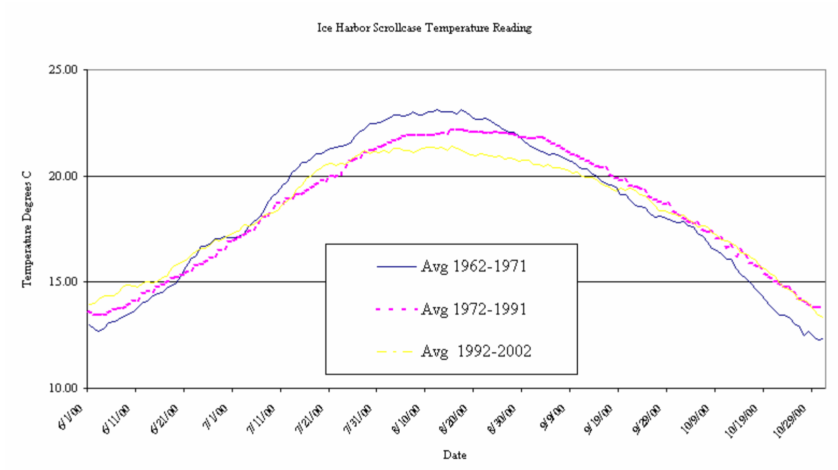

Figure 5. Water temperatures as measured at the Ice Harbor Dam Scrollcase, 1962-2002.

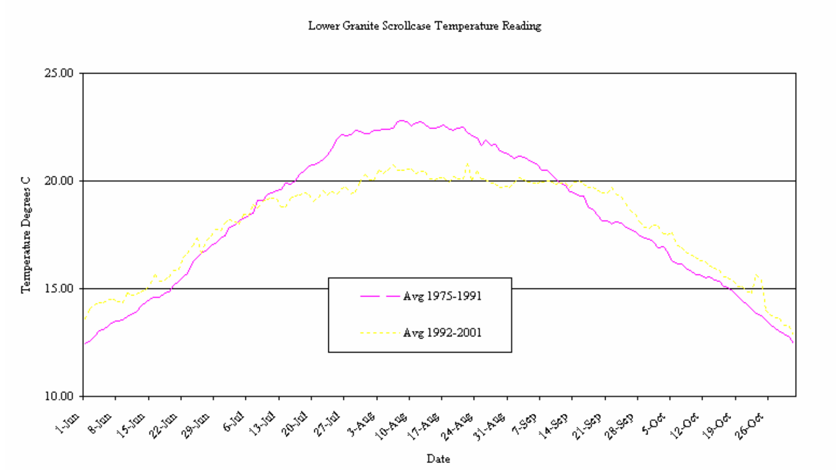

Figure 6. Water temperatures as measured at the Lower Granite Dam Scrollcase 1975-2001

13.1.2 BIOP RPA

Reasonable and Prudent Alternative (RPA) 18 provides guidelines on the operations of Hungry Horse, Libby, Albeni Falls, Grand Coulee and Dworshak dams and reservoirs. The primary emphasis of this RPA is to provide guidance for the operations of the storage reservoirs including strategic reservoir elevations and discharges during specific times of the year to benefit resident and anadromous fish. Dworshak Dam is the only storage project that is recommended for implementing temperature measures. The RPA states, "The Action Agencies shall manage Dworshak discharge to attempt to maintain water temperatures at the Lower Granite Reservoir forebay dissolved gas monitoring station at or below 68°F (20°C)."

13.1.3 Major Issues and Concerns

13.1.3.1 Negative Impacts to Rearing Juvenile Fall Chinook

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 m3/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)

13.1.3.2 Balancing of reservoir elevation versus augmentation

Currently, storage projects are prioritized to fill by June 30 (RPA 18), 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 may reduce the potential to refill to the appropriate level.

13.1.3.3 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.

13.1.3.4 Higher TDG Levels With Dworshak Discharge Rate

Spillway, low level regulating outlets and some turbine operations at Dworshak Dam can produce increased levels of total dissolved gas (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 a US Fish and Wildlife fish hatchery (Dworshak 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.

13.1.3.5 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.

13.1.3.6 SOR EIS

Further discussions of the effects can be found in the 1995 Columbia River System Operation Review/ Final EIS.

13.1.4 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.

13.1.5 Schedule

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

13.2 (M-2) Examine the Benefits of Drafting Dworshak an Additional 20 Feet during 13.3 September to provide cool water to the mainstem.

13.3.1 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.

Figure 7 demonstrates that the time period in September is warmer for a longer than what occurred prior to the Dworshak operations. It also demonstrates how cool water releases into September could cool the latter part of the fall water temperatures.

13.3.2 BIOP RPA

RPA 34 states that, “Action Agencies (AA) shall evaluate potential benefits to adult Snake River steelhead and fall Chinook salmon passage by drafting Dworshak Reservoir to elevation 1,500 feet in September. An evaluation of the temperature effects and adult migration behavior should accompany a draft of Dworshak Reservoir substantially below elevation 1,520 feet.”

It also states, “an evaluation should be conducted to assess the effects of the September draft on lower Snake River temperatures and on the migratory behavior and passage timing of adult salmonids that are equipped with depth and temperature-sensitive tags. An evaluation of

Dworshak refill probability indicates that this study operation would have little impact on reservoir refill by the end of June in the following year, i.e., two additional refill misses in BPA's 50-year hydrosystem study."

13.3.3 Major Issues and Concerns

13.3.3.1 Risk to reservoir refill and reduction of spring flows

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. 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 of Dworshak refill probability indicates the September Adult study operation, when conducted, 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. For comparison, the single refill miss under the proposed action was 15 feet from full pool. NMFS believes that this is an acceptable risk to refill of the June 30 full pool.

Moreover, a 50-year hydro-regulation study of Dworshak refill probability indicates the September adult study operation, when conducted, has no discernable effect on reservoir refill to upper rule curve elevation by April 10, and little to no effect on spring flows.

13.3.3.2 Higher TDG Levels With Dworshak Discharge Rate

As previously discussed in section 5.1.3.4, 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.

13.3.3.3 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 (See Section 5.5.3.4)

13.3.3.4 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.

13.3.3.5 Recreation

Drawing Dworshak Reservoir down 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.

13.3.3.6 Bull trout

As mentioned in Section 5.1.3.5, 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.

13.3.3.7 SOR EIS

Further discussions of the effects can be found in the 1995 Columbia River System Operation Review/ Final EIS.

13.3.4 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).

13.3.5 Schedule

Studies began in 2002 and are ongoing.

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

13.4.1 Introduction

Lower Snake River reservoirs that are operated at lower elevations have a reduced cross-sectional area, thereby increasing water velocity at a given flow. As a result, reduced water particle travel time can help to reduce the amount of warming that occurs due to solar radiation. In addition, juvenile migrants have demonstrated faster travel with increased water velocities; therefore drawdown to MOP would be expected to provide faster emigration and improved survival (NMFS 2000).

13.4.2 BIOP RPA

RPA 20 states, "The Corps shall operate the lower Snake River reservoirs within 1 foot of MOP from approximately April 3 until small numbers of juvenile migrants are present …" In addition, "Lower Granite Dam should not be refilled until enough natural cooling has occurred in the fall, generally after October 1."

13.4.3 Major Issues and Concerns

13.4.3.1 Dredging Injunction

The Corps' Walla Walla District completed a Dredged Material Management Plan and Environmental Impact Statement in 2002 for the Lower Snake River Reservoirs and McNary Reservoir. Dredging the navigation channel at the confluence of the Snake and Clearwater Rivers and the tailraces of Lower Granite and Lower Monumental dams was scheduled for the winter of 2003. However, a lawsuit was filed just prior to dredging, and an emergency injunction to the dredging was granted. As a result, in some locations, the navigation channel was not at the authorized 14 foot of depth at MOP or MOP+1 in some locations.

In the 2003 BiOp implementation plan, the Corps stated its intention to operate the lower Snake River reservoirs within 1 foot of MOP. The Corps notified NOAA Fisheries of its decision on operational needs at Snake River projects for 2003, including any proposed deviations from MOP criteria.

A Final Environmental Impact Statement for a one-time channel maintenance action was completed in 2005. A settlement agreement was reached with the plaintiffs in September 2005 and the Corps was allowed to dredge specific areas of the river during winter 2005-2006. Dredged material was used to build fish habitat near river mile 116.

13.4.3.2 Decreased Power Generation and System Flexibility

When the reservoir behind the Lower Snake River Dams is 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.

13.4.4 SOR EIS

Further discussions of the effects can be found in the SOR EIS.

13.4.5 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.

13.4.6 Schedule

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

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

13.5.1 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.

As mentioned in 4a, decreased reservoir elevation would lead to faster water particle travel time and reduce the overall exposure to solar radiation.

13.5.2 BIOP RPA

None

13.5.3 Major Issues and Concerns

13.5.3.1 Negative 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 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 inriver (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. The NMFS 2000 FCRPS Biological Opinion supports this.

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.

13.5.3.2 Negative 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.

13.5.3.3 Negative impacts to Navigation/Hydropower/Infrastructure

Drawdown of the lower Snake River reservoirs during periods of high temperatures 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.

13.5.3.4 Negative impacts to Cultural Resources

While collecting/vandalism was recognized as a potential problem during the 1992 drawdown test, it occurred at 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).

13.5.4 SOR EIS

Further discussions of the effects can be found in the 1995 Columbia River Salmon Flow measures Option Analysis/EIS

13.5.5 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.

13.5.6 Schedule

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

13.6 <u>(M-3c) Operate Lower Granite Reservoir at Spillway Crest year round.</u>

13.6.1 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.

13.6.2 BIOP RPA

None

13.6.3 Major Issues and Concerns

13.6.3.1 Negative impacts to salmonids

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

13.6.3.2 Negative 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. For a discussion on repetitive drawdowns on the reservoir, please see section 5.4

13.6.3.3 Negative impacts to Navigation/Hydropower/Infrastructure

Permanent drawdown of the Lower Granite Reservoir eliminate 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.

13.6.3.4 Negative impacts to Cultural Resources

As in section 5.4, cultural resources would be exposed to potential damage and/or looting.

13.6.4 Feasibility and Implementation

Because of the negative impacts listed in section 5.7.3, this operation has been determined by the Corps to be “not feasible” and is not planned for implementation.

13.6.5 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.

13.7 <u>(M-3d) Remove Dams and Reservoirs</u>

13.7.1 Introduction

Two studies have recently 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. If determined that changes to water temperature cannot be accomplished through other means, removing all dams or those that have the highest impact to water temperatures may warrant consideration. The primary focus of this section, however, will remain on the removal of Lower Snake River dams because this is related to the 2005 and 2008 NMFS 2000 BiOp Check-in evaluations.

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.

13.7.2 BIOP RPA

None

13.7.3 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, all facilities for transporting fish would cease to operate, as would hydropower operation. Other impacts include the exposing of cultural resources, an impact to the economy of the region and the reduction of water transportation to Idaho. The navigation locks would no longer be operational, and navigation for commercial and large recreation vessels would be curtailed. 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 unimpounded lower Snake River would require important and substantial changes. Under Alternative 4—Dam Breaching, 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. Although it has not been modeled, releases of water from Dworshak Dam could be reduced if there is an overall smaller volume of water to cool where the 4 lower Snake River dams and reservoirs currently exist. Whatever releases do occur might also be more effective further downstream without the delay of travel through intervening reservoirs.

13.7.4 Feasibility and Implementation

Of the four alternatives investigated in the FR/EIS, the recommended plan of major system improvements most closely matches the recommendations in the NMFS 2000 Biological Opinion for the Lower Snake River Project. The NMFS 2000 Biological Opinion concluded that dam breaching on the lower Snake River is not necessary at this time, but reserved this action as a contingency management alternative if the listed stocks continue to decline in the near future (2005 to 2008). The Corps' selection of a modified version of Alternative 3—Major System Improvements (Adaptive Migration) as the recommended plan (preferred alternative) is consistent with this conclusion.

The plan includes implementation of the actions applicable to the Corps as recommended in the NMFS 2000 Biological Opinion and the USFWS 2000 Biological Opinion for system operations, configuration measures, habitat restoration, and continued research and monitoring activities (or alternative measures that result in achieving the current or revised established performance standards). In implementing the Biological Opinions' lower Snake River actions, the Corps will also contribute to the attainment of the goals identified in the Conservation of Columbia Basin Fish: Final Basinwide Salmon Recovery dated December 2000. This strategy was developed by several Federal agencies (including the Corps) as part of the Federal Caucus. It is a comprehensive, long-term plan to recover 12 anadromous fish stocks and other listed species (i.e., bull trout and sturgeon) in the Columbia-Snake River Basin.

Analyses of the effects of dam breaching on water temperature was based on both empirical data and model simulations. The results of these two analysis methods vary slightly but are in agreement. The U.S. Environmental Protection Agency (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.)

Further information on modeling water temperatures in the geographic scope of this plan will be available in the near future. EPA is developing much of this information for the TMDL process. Because the models being used for this have been updated since the Corps 2002, the newer modeling runs may present different results as what was presented in the previous section.

13.7.5 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.

13.8 <u>(M-3e) Draw down John Day Reservoir to spillway crest or natural river.</u>

13.8.1 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)

13.8.2 BIOP RPA

None

13.8.3 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:

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

13.8.3.1 Negative impacts to salmonids

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

13.8.3.2 Negative biological impacts to reservoir

Similar negative impacts to salmonids outlined in measure M-3c including primarily negative impacts to salmonids from reduced reservoir health.

13.8.3.3 Negative 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.

13.8.3.4 Negative impacts to 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.

13.8.4 Feasibility and Implementation

The Corps has determined that this operation is "Not Feasible" because of little improvements for migrating anadromous fish, negative impacts to wildlife, and a very large cost (See section 5.6.3).

13.8.5 Schedule

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

13.9 (M-3f) Draw down other dams to spillway crest or natural river temporarily or 13.10 year round.

13.10.1Introduction

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.

13.10.2BIOP RPA

None

13.10.3Major Issues and Concerns

13.10.3.1 Negative impacts to salmonids

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

13.10.3.2 Negative biological impacts to reservoir

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

13.10.3.3 Negative impacts to Navigation/Hydropower/Infrastructure

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

13.10.3.4 Negative impacts to Cultural Resources

As in section 5.4, cultural resources would be exposed to potential damage and/or looting.

13.10.4 Feasibility and Implementation

Unknown

13.10.5 Schedule

Unknown

13.11 (M-4) Grand Coulee Powerhouse Operations.

13.11.1 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.

13.11.2 BIOP RPA

None directly associated with it

13.11.3 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.

13.11.4 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.

13.11.5 Schedule

TBD

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

13.12.1 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 storage reservoirs in the subject area are Grand Coulee, Brownlee and Dworshak.

13.12.2 BIOP RPA

None

13.12.3 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.

13.12.4 Feasibility and Implementation

No additional action is expected on this item.

13.12.5Schedule

None

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

13.13.1 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.

13.13.2 BIOP RPA

None

13.13.3 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.

13.13.4 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.

13.13.5 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.

13.14 <u>(M-5c) Hell's Canyon hydroprojects.</u>

13.14.1 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 deeply in the water column (about 40 m below full pool elevation). The magnitude of flows in a year appears to affect the amount of cooling. In high-water years, like the late 1990s, when the COE mandates 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 an obvious 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 TMDL was approved. The Snake-River Hells-Canyon 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 of several temperature control devices were investigated in cooperation with agencies and using a combination of modeling efforts. Results show that the Snake River-Hells Canyon load allocation could be met with a TCS located at Brownlee Reservoir. However, the modeling also shows that no clear benefit to fall Chinook is realized by operation of a TCS to meet the SR-HC load allocation, and the potential for harm exists (e.g. release of anoxic cool water, changing Brownlee thermal structure). Based on the results from the detailed modeling effort undertaken by IPC and 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 surrounding the Snake River-Hells Canyon load allocation.

The availability of cool water in Brownlee for temperature control follows the same pattern with flow years as mentioned above with deep stored water being warmer in high flow years than low flow years. Additionally the volume of water stored in the hypolimnion is very limited due to deep formation of the thermocline and the long narrow canyon characteristics of Brownlee. Conceptually, in order to store additional cool water, a temperature control device could raise the elevation of the thermocline by withdrawing water closer to the reservoir surface. Raising the thermocline would store addition cool water (increase hypolimnion size) and also warm spring outflow temperatures over what occurs currently (warming spring outflow temperatures would conceptually accelerate fall Chinook emergence). The additional cool water stored could then be released in the summer and/or fall to cool outflow temperatures. Withdrawing water from near the surface of the reservoir during the spring both increases the outflow temperatures and stores more cool water; therefore, spring warming and summer/fall cooling are complementary to one another (i.e., they can occur in the same year). However, as the volume of stored cool water in Brownlee Reservoir is finite, once a given volume is used to cool the outflow, it is gone until the reservoir again stratifies the following year. Since the volume of cool water is finite, the use of that water to cool the outflows in the summer means that less cool water will be available in the fall to use for a similar purpose. Conversely, if the cooler water is used for fall cooling, less cool water will be available for cooling during the summer. Thus, cooling both summer and fall outflows are not complementary and require management decisions to optimize use of stored cold water.

13.14.2 BIOP RPA

None

13.14.3 Major Issues and Concerns

There is considerable uncertainty associated with changes in Brownlee in-reservoir conditions. There are questions of how much cool water there is in Brownlee, 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 may be anoxic, which may result in lowered downstream DO. Significant cool water storage would only be possible by raising the current thermocline level in Brownlee. This will change the entire thermal structure and possibly move anoxic layers closer to the surface where more potential for periodic mixing would occur.

13.15 (M-6) Alter the Flood Control Rule Curves

13.15.1 Introduction

System flood control strongly influences streamflow characteristics in the mainstem Snake and Columbia rivers. As described in Section 6 of the BiOp, these hydrologic effects affect juvenile salmon survival. While current flood control operations routinely reduce even non-damaging floods, peak flows of historical magnitude (e.g., the 1948 Vanport flood) could result in substantial damage. The intent of this measure would be to refine flood control operations such that they cause the least possible reduction in runoff volumes and the probability of reservoir refill while maintaining high levels of protection from damaging floods. 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, however, was based on the fundamental premise *"that the existing flood control capability ...would remain unchanged after any rule curve modifications were made* (Corps 1991)." Thus, *"...it is conceivable that flood control criteria could be reduced substantially, and levees raised a corresponding amount to compensate."*

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 for this measure is 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 to a real-time basis. A thorough investigation of new forecasting technologies would enhance system response and afford greater precision in system flood control operations.

13.15.2 BIOP RPA

Action 35: The Corps shall develop and conduct a detailed feasibility analysis of modifying current system flood control operations to benefit the Columbia River ecosystem, including salmon. The Corps shall consult with all interested state, Federal, Tribal, and Canadian agencies in developing its analysis. Within 6 months after receiving funding, the Corps shall provide a feasibility analysis study plan for review to NMFS and all interested agencies, including a peer-review panel (at least three independent reviewers, acceptable to NMFS, with expertise in water management, flood control, or Columbia River basin anadromous salmonids). A final study plan shall be provided to NMFS and all interested agencies 4 months after submitting the draft plan for review. The Corps shall provide a draft feasibility analysis to all interested agencies, NMFS, and the peer-review panel by September 2005.

The Corps completed a reconnaissance-level study in January of 2006 and released the report for public review and comments. The report concluded that there is a Federal interest in pursuing a feasibility-level study to determine if the system flood control review objectives can be met. The reconnaissance study specifically identified a number of potential alternatives to existing Columbia River Flood control systems that could benefit ESA-listed fish species while maintaining acceptable levels of protection from damaging floods and recognizing project purposes. The study also identified issues and data gaps (i.e. stage-damage relationships, definition of acceptable levels of damage reduction, levee assessments) that would need to be addressed prior to any selecting and implementing alternative plans for system flood control operations.

The reconnaissance study was funded using funds appropriated as part of the Columbia River Fish Mitigation (CRFM) Program to initiate an investigation of flood control operations. In addition to providing funding for the study, Senate Committee language states, “Evaluation beyond the reconnaissance phase is subject to agency review and congressional notification.” Consistent with the Senate language, the reconnaissance study also identified the need to coordinate closely with the regional stakeholders to ensure support for more detailed feasibility-level study and eventual implementation of potential alternative system operations resulting from future project phases.

The regional review revealed limited and qualified support for moving into feasibility level study of potential modification of Columbia River system flood control for benefit of salmonids while considering the multiple uses of the system. Review by regional stakeholders also identified several other issues that could potentially conflict or adversely affect the scope, funding, or schedule of a system flood control feasibility effort. The regional input provided important context to the Corps in evaluating the potential risks and benefits of proceeding with the project. The following topics were the primary issues identified by regional stakeholders:

- Limited regional support for a feasibility study on system flood control;
- Columbia River Treaty issues;
- Consideration of the ongoing remand of the 2004 NMFS biological opinion on the operation of the FCRPS;
- Use of CRFM funds as the funding source; and
- High cost of feasibility study.

After close review of the Region’s comments and consideration of issues discussed above, the Corps has decided to suspend the feasibility study on the Columbia River Fish Mitigation System Flood Control Review until a later date. Since no further work will be done at this time, no Congressional notification is required now, but it would be needed to move into feasibility at some later date. The project will most likely be re-evaluated and a final decision on whether to re-start or shut down the project after the decision on the Remand has been finalized in 2007, and the scope and project management plan for the re-evaluation of the Columbia River Treaty has been drafted and finalized.

13.15.3 Major Issues and Concerns

13.15.3.1 River Hydrology

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 during late summer and fall.

Furthermore, flood control concepts are changing. 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, the Corps may identify 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). 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).

13.15.3.2 Other Concerns

The effects that changing the flood control rule curves are varied and numerous and will only be touched on lightly here. 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, would pushing more water downstream during the spring, thus causing more total dissolved gas, out weigh the benefits of flushing fish out of the system earlier? These and many other questions would need to be addressed in a recon or feasibility study.

13.15.4 Feasibility and Implementation

The primary objectives of a feasibility analysis would include reducing the effects of flood control operations on the spring freshet, particularly during average to below-average runoff years; minimizing flow fluctuations during fall Chinook emergence and rearing; and achieving a high probability of reservoir refill, particularly at Dworshak, Grand Coulee, Hungry Horse, and Libby reservoirs, while maintaining acceptable levels of protection for developed areas within the active floodplain. This analysis will consider all aspects of flood control, including the flood control target flow(s), associated storage reservation diagrams, the method of calculating the initial control flow, and the timing and coordination of flood control management. The study will incorporate the best currently available forecast technology for estimating runoff and peak flows. Innovative concepts, such as using an expert system to define operations in real time, which would increase system flexibility or the ability to achieve the above stated objectives should be incorporated to the extent practical. New storage reservation diagrams should include mechanisms for interpolation to facilitate higher storage contents going into the spring in some years. The Corps will also identify those improvements necessary to facilitate higher flood control target flows and estimate the cost and time needed to implement such improvements. This analysis will include all Federal, non-Federal, and Canadian projects currently operated for system flood control. Because modifying flood control operations would affect an array of interests, the Corps should consult with all interested state, Federal, Tribal, and Canadian agencies in developing its analysis. The final feasibility report will include a proposed action and respond to all concerns and comments on the draft.

13.15.5 Schedule

A schedule for a feasibility stage study has not been determined.

13.16 <u>(M-7) Investigate cool water releases from Canadian hydro projects.</u>

13.16.1 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.”

13.16.2 BIOP RPA

None

13.16.3 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. This may need further discussion in treaty negotiations.

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.

13.16.4 Feasibility and Implementation

Unknown

13.16.5Schedule

Unknown

13.17 <u>(M-8) Investigate Banks Lake selective withdrawal to draw warm water from Lake Roosevelt.</u>

13.17.1 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.

13.17.2 BIOP RPA

None

13.17.3 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.

13.17.4 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.

13.17.5Schedule

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.

13.18 <u>(M-9) Investigate Groundwater Charging to Cool Mainstem Water</u>

13.18.1 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.

13.18.2 BIOP RPA

None

13.18.3 Major Issues and Concerns

This is a novel approach at cooling river water. The benefits are outlined in Section 5.15.1, however, 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.

13.18.4 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 11) 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.

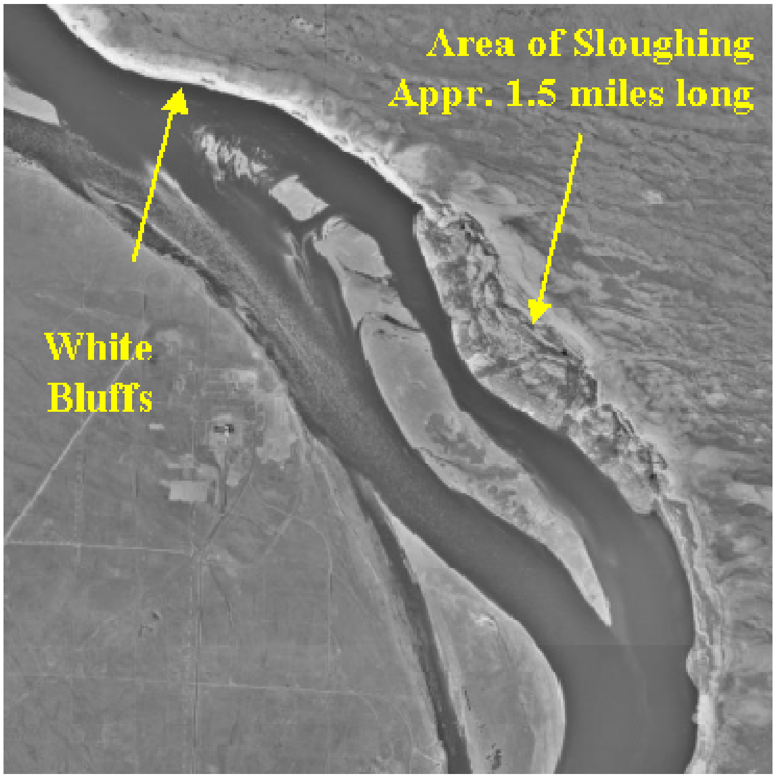

Figure 11. Aerial photo of the White Bluffs area of the Columbia River with severe sloughing of the white bluffs indicated right of center.

In 1997, the Geological Survey published a study on the decades of seepage (Could not find this study), looking 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 brushed over and if looked into, should be taken seriously as 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.

13.18.5 Substrate

According to the US department of agriculture (http://www.uswcl.ars.ag.gov/IWQ/waterp~1/recharge.htm), 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, in reference to section 5.15.4 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.

13.18.6 Present Reservoir Connectivity with Groundwater

In section 5.15.4, there are discussions regarding how the creation of artificial reservoirs contributed to groundwater, however, 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.

13.18.7 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 (http://ks.water.usgs.gov/Kansas/pubs/abstracts/ofr.02-89.html), "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

13.18.8 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.

13.18.9Schedule

Unknown

14 Proposed Site Specific Water Temperature Measures

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

14.1.1 Introduction

As indicated in the BiOp, improvements to the Dworshak National Fish Hatchery water supply would isolate hatchery operations from the effect of Dworshak Reservoir operations. At the date of publication of the BiOp, Dworshak Reservoir releases could not be conducted for optimal temperature releases because of likely adverse effects of cold water on hatchery rearing performance. This problem could be resolved by making improvements in the hatchery water supply system to accommodate releases of cooler water from Dworshak.

14.1.2 BIOP RPA

RPA 33 states, "The Corps, in coordination with USFWS, shall design and implement appropriate repairs and modifications to provide water supply temperatures for the Dworshak National Fish Hatchery that are conducive to fish health and growth, while allowing variable discharges of cold water from Dworshak Reservoir to mitigate adverse temperature effects on salmon downstream in the lower Snake River."

14.1.3 Major Issues and Concerns

Continued negative impacts would occur to the hatchery operations if this work were not done. Although most juvenile fall Chinook have moved out of the Snake River by August 1, the release of cooler water from the dam may have greater impacts to juvenile salmon rearing in the Clearwater River.

14.1.4 Feasibility and Implementation

This measure is feasible. Construction is currently underway and should be completed by the 2003 rearing period at Dworshak hatchery. Further discussions may need to be held regarding the appropriate temperature of water to be released from the reservoir.

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

14.2.1 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.

A proposed action at McNary Dam 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, or 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.

14.2.2 BIOP RPA

Action 141: The Action Agencies shall evaluate juvenile fish condition due to disease in relation to high temperature impacts during critical migration periods. This evaluation should include monitoring summer migrants at lower Columbia and lower Snake river dams to clarify the possible link between temperature and fish disease and mortality. This information will be used to assess the long-term impacts of water temperature on juvenile fish survival. High water temperatures have been linked to stress and disease in fish. It is essential 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.

Action 142: The Corps shall work through the regional forum process to identify and implement measures to address juvenile fish mortality associated with high summer temperatures at McNary Dam. As a starting point, the Corps shall assemble and analyze the temperature data that have been recorded in the McNary forebay, collection channel, and juvenile facilities. The Corps shall examine relationships among juvenile mortality, temperatures, river flow rates, and unit operations in detail. The Corps shall investigate the feasibility of developing a hydrothermal computational fluid dynamics model of the McNary forebay to evaluate the potential to determine optimal powerhouse operations or structural modifications for minimizing thermal stress of juvenile salmon collected in the summer and to conduct a modeling program, if warranted.

14.2.3 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).

14.2.4 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.

14.2.5 Schedule

Studies started in 2000 are continuing and are ongoing. Included in these studies was the development of a three-dimensional computational flow dynamics model of the McNary forebay which extends roughly a few miles upstream. This is a finer scaled model than is used in other areas of the basin. It will be used to examine the effects of some of the proposed configuration and operational measures being considered at McNary, and the effectiveness of those measures in mitigating thermal stress.

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

14.3.1 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 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.

14.3.2 BIOP RPA

None directly associated

14.3.3 Major Issues and Concerns

If a problem were discovered, a solution would need to be developed.

14.3.4 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.

14.3.5 Schedule

Nothing is scheduled on this proposed action.

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

14.4.1 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 action 7d. 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.

14.4.2 BIOP RPA

None directly associated with it

14.4.3 Major Issues and Concerns

If a problem were discovered, a solution would need to be developed as well.

14.4.4 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.

14.4.5 Schedule

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

15 Proposed Research Water Temperature Measures

15.1 (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.

15.1.1 Introduction

As mentioned in section 5.1.3.3, 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.

15.1.2 BIOP RPA

Action 34: The Action Agencies shall evaluate potential benefits to adult Snake River steelhead and fall Chinook salmon passage by drafting Dworshak Reservoir to elevation 1,500 feet in September. An evaluation of the temperature effects and adult migration behavior should accompany a draft of Dworshak Reservoir substantially below elevation 1,520 feet. The rationale for evaluating an additional 20-foot draft of Dworshak Reservoir in September is to determine whether cooling Snake River temperatures during September would provide an adult passage benefit. The potential benefits are 1) reduction in water temperature, 2) possible elimination of a thermal block that delays adult migration into and through the lower Snake River, and 3) improved gamete viability. An evaluation should be conducted to assess the effects of the September draft on lower Snake River temperatures and on the migratory behavior and passage timing of adult salmonids that are equipped with depth and temperature-sensitive tags. An evaluation of Dworshak refill probability indicates that this study operation would have little impact on reservoir refill by the end of June in the following year, i.e., two additional refill misses in BPA's 50-year hydrosystem study.

Action 115: The Corps and BPA shall conduct a comprehensive depth and temperature investigation to characterize direct mortality sources at an FCRPS project considered to have high unaccountable adult losses (either from counts and/or previous adult evaluations). Previous radiotelemetry investigations have been two-dimensional and have attempted to characterize passage routes and timing of successfully passing fish. This study will also attempt to focus on those fish that do not successfully pass and determine whether a consistent source of mortality can be identified and corrected.

15.1.3 Major Issues and Concerns

There are no major concerns with this work. However, if a problem were discovered, a solution would need to be developed.

15.1.4 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

15.1.5 Schedule

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

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

15.2.1 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.

15.2.2 BIOP RPA

Action 114: The Corps shall examine existing fish-ladder water temperature and adult radiotelemetry data to determine whether observed temperature differences in fishways adversely affect fish passage time and holding behavior. If non-uniform temperatures are found to cause delay, means for supplying cooler water to identified areas of warmer temperatures should be developed and implemented in coordination with the annual planning process.

15.2.3 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.

15.2.4 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 (US 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 2007, 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.

15.2.5 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 2007, Phase 4 would lead to the installation of some type of temperature control device at Lower Granite in 2008, at the earliest.

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

15.3.1 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.

To examine the temperature releases from Dworshak Dam, the Corps, in cooperation with Battelle’s Pacific Northwest National Laboratory, has been working with a three-dimensional computational flow dynamics model. This model exists for selected reaches of the Lower Snake river and McNary reservoirs.

15.3.2 BIOP RPA

Action 143: By June 30, 2001, the Action Agencies shall develop and coordinate with NMFS and EPA on a plan to model the water temperature effects of alternative Snake

River operations. The modeling plan shall include a temperature data collection strategy developed in consultation with EPA, NMFS, and state and Tribal water quality agencies. The data collection strategy shall be sufficient to develop and operate the model and to document the effects of project operations. The modeling plan should focus on water temperatures in the Snake River from Hells Canyon Dam and from Dworshak Dam on the North Fork of the Clearwater River to Bonneville Dam on the Columbia River. Predictive nodes should be located at the near-dam forebays and tailraces of each project. Both one- and multi-dimensional models (due to reservoir stratification) may be needed to fully define expected temperature conditions within the reach. The models should be developed to function both as a pre-season planning tool and to provide predicted outcomes of immediate operations in real time to assist in the in-season water management decision process. Existing water temperature and meteorological data may be inadequate for this purpose. Existing data and statistical tools will be used to identify locations where additional or improved data collection, in terms of precision, accuracy and frequency, would be most beneficial.

15.3.3 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.

15.3.4 Feasibility and Implementation

Work on this project began in March 2002 upon receipt of funding. 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.

15.3.5 Schedule

This study began in 2002 and is planned through 2007.

The major activities completed to date include:

1. Establishment of team - March 8, 2002
2. Initiation of data collection efforts - May 2002
3. Progress report issued - September 10, 2002
4. Complete review of existing data and reports
5. Complete data collection/analysis and reporting
6. Selection of CE-QUAL-W2 as model of choice
7. Development of data collection strategy

8. Implement data collection strategy
9. Completion of annual reports and regional meetings

FY2002-2003 Tasks

1. Screening available data
2. Initiate new data collection

FY2004 Tasks

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

FY2005 Tasks

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

FY2006 Tasks

1. Expand to Phase 3 Geographic Scope
2. Revise data collection as needed to support Phase 3 and other model inputs and improvements

FY2007 Tasks

1. Implementation at Walla Walla District and Northwestern Division
2. Model optimization

15.4 <u>(R-3b) Improve water temperature monitoring of the Columbia River System.</u>

15.4.1 Introduction

Agencies in the Columbia River Basin currently monitor a minimum of 40 sites for temperature with the TDG monitoring program. For further detail, please refer to section 1.5.

15.4.2 BIOP RPA

Action 143: By June 30, 2001, the Action Agencies shall develop and coordinate with NMFS and EPA on a plan to model the water temperature effects of alternative Snake River operations. The modeling plan shall include a temperature data collection strategy developed in consultation with EPA, NMFS, and state and Tribal water quality agencies. The data collection strategy shall be sufficient to develop and operate the model and to document the effects of project operations. The modeling plan should focus on water temperatures in the Snake River from Hells Canyon Dam and from Dworshak Dam on the North Fork of the Clearwater River to Bonneville Dam on the Columbia River.

Predictive nodes should be located at the near-dam forebays and tailraces of each project. Both one- and multi-dimensional models (due to reservoir stratification) may be needed to fully define expected temperature conditions within the reach. The models should be developed to function both as a pre-season planning tool and to provide predicted outcomes of immediate operations in real time to assist in the in-season water management decision process. Existing water temperature and meteorological data may be inadequate for this purpose. Existing data and statistical tools will be used to identify locations where additional or improved data collection, in terms of precision, accuracy and frequency, would be most beneficial.

15.4.3 Major Issues and Concerns

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

15.4.4 Feasibility and Implementation

A study is currently in progress that is analyzing the locations of TDG monitors. This study would be expected to be placing the monitors in the expected locations that would be best for temperature monitoring as well.

15.4.5 Schedule

This study began in 2002 and is planned through 2007 in combination with the TDG monitoring program.

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

15.5.1 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.

15.5.2 BIOP RPA

None

15.5.3 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.

15.5.4 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.

15.5.5 Schedule

Unknown

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

15.6.1 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.

15.6.2 BIOP RPA

None

15.6.3 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.

15.6.4 Feasibility and Implementation

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

15.6.5 Schedule

Unknown

15.7 (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.

15.7.1 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 models were primarily designed to simulate the effects of cool water releases from Dworshak Dam and water temperatures through the powerhouse.

15.7.2 BIOP RPA

For Lower Snake, RPA 143.

15.7.3 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.

15.7.4 Feasibility and Implementation

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

15.7.5 Schedule

Unknown

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

15.8.1 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.

15.8.2 BIOP RPA

Action 141: The Action Agencies shall evaluate juvenile fish condition due to disease in relation to high temperature impacts during critical migration periods. This evaluation should include monitoring summer migrants at lower Columbia and lower Snake River dams to clarify the possible link between temperature and fish disease and mortality. This information will be used to assess the long-term impacts of water temperature on juvenile fish survival.

15.8.3 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 requirements of the RPA. 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.

15.8.4 Feasibility and Implementation

Feasibility

15.8.5 Schedule

Unknown

16 Conclusions

This document is meant to address part of the plans requested through Appendix B of the 2000 NMFS FCRPS Biological Opinion. In this document, the Corps has presented the background of temperature issues in the Columbia River Basin, the rationale for preparing the document, what has been done and what has been proposed to address water temperature issues, and supporting information for each of these measures. Much of the background information was taken from documents found in the citations, from assisting government agencies, or gathered from personnel in the Northwest Division or Portland, Seattle or Walla Walla District, Corps of Engineers. This document was not meant to be all-inclusive, in that the complete history of water temperature issues in the Columbia Basin could make for an unwieldy document and could overwhelm the reader, rather, it was meant to provide a background of temperature issues and how the Action Agencies has dealt with and is attempting to deal with them.

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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.

Table A-1 Monitoring System Schedule

Action Item #	Type Of Measure	Project Location	TDG Measures	Major Issues or Concerns	Lead Agency	Status/ Year(s)	TMDL IP Phase	NMFS 2000 FCRPS RPA
Monitoring 1	Study	FCRPS	Review/Analysis of WQ Monitors			Dec-02		
Monitoring 2	Fieldwork	FCRPS	Install Equipment for WQ Monitors			Mar-03		
Monitoring 3	Monitoring	FCRPS	Report on WQ Monitors			Sep-03		

Table A-2 Overall System

Action Item #	Type Of Measure	Project Location	TDG Measures	Major Issues or Concerns	Lead Agency	Status/ Year(s)	TMDL IP Phase	NMFS 2000 FCRPS RPA
Systemwide 1	Study	FCRPS	DGAS		Corps	1994-2002		
Systemwide 2	Plans	FCRPS	NMFS FCRPS Biological Opinion		NMFS	2000		
Systemwide 3	Activity	FCRPS	Predator Removal/Abatement			Ongoing	II	
Systemwide 4	Operations	FCRPS	Improved O&M			Ongoing	II	
Systemwide 5	Studies	FCRPS	Turbine Survival Program			Phase I - 2003 Phase II - 2004	II	
Systemwide 6	Model	FCRPS	SYSTDG			2000		
Systemwide 7	Bio Study	FCRPS	Investigate if Adult Head Burn is Caused by High TDG			2001-2004		

Table A-3 Federal Mid Columbia River

Action Item #	Type Of Measure	Project Location	TDG Measures	Major Issues or Concerns	Lead Agency	Status/ Year(s)	TMDL IP Phase	NMFS 2000 FCRPS RPA
Fed Mid-C - 1	Operational	Grand Coulee	Shift spill to Chief Joseph Dam			2004		
Fed Mid-C - 2	Physical	Grand Coulee	Submerge spill by extending outlet tubes			?		
Fed Mid-C - 3	Studies	Chief Joseph	Physical Model Built			1999		
Fed Mid-C - 4	Studies	Chief Joseph	Flow Deflector Models Tested			2000		
Fed Mid-C - 5	Operational	Chief Joseph	Shift power generation to Grand Coulee Dam			2004		
Fed Mid-C - 6	Physical	Chief Joseph	Flow Deflectors			2005-2008	I	

Table A-4 Hells Canyon

Action Item #	Type Of Measure	Project Location	TDG Measures	Major Issues or Concerns	Lead Agency	Status/ Year(s)	TMDL IP Phase	NMFS 2000 FCRPS RPA
Hells-C - 1	Study	Brownlee	TDG Monitoring			1997, 1998, 2006		
Hells-C - 2	Study	Oxbow	TDG Monitoring			1997, 1998, 2006		
Hells-C - 3	Study	Hells Canyon	TDG Monitoring			1997, 1998, 1999, 2006		
Hells-C - 4	Study	Hells Canyon	Flow Deflectors			2000		
Hells-C - 5	Study	Brownlee	Flow Deflectors			2005		

Table A-5 Clearwater River

Action Item #	Type Of Measure	Project Location	TDG Measures	Major Issues or Concerns	Lead Agency	Status/ Year(s)	TMDL IP Phase	NMFS 2000 FCRPS RPA
Clearwater 1	Study	Dworshak	Identify potential methods of reducing production of TDG.		Corps	TBD – Not Currently Funded		139
Clearwater 2	Physical	Dworshak	Modifications as recommended by TDG study. Modifications may include spillway modifications, Turbine Installation etc.		Corps	TBD Based on Clearwater 1		139
Clearwater 3	Physical	Dworshak	Spillway Modifications		Corps	TBD		139
Clearwater 4	Physical	Dworshak	Turbine Installation		Corps	TBD		139
Clearwater 5	Study	Dworshak	Hydrologic Analysis		Corps	TBD		139
Clearwater 6	Study	Dworshak	Model Construction		Corps	TBD		139

Table A-6 Lower Snake River

Action Item #	Type Of Measure	Project Location	TDG Measures	Major Issues or Concerns	Lead Agency	Status/ Year(s)	TMDL IP Phase	NMFS 2000 FCRPS RPA
Lower Snake 1	Bio Study – Physical – Operational	Lower Granite	Surface Bypass Collection			1995 – 2000		
Lower Snake 2	Study – Physical – Operational	Lower Granite	Gas Fast Track			Not funded due to low priority ranking by SCT		
Lower Snake 3	Study	Lower Granite	- Sectional Hydraulic Model			TBD		
Lower Snake 4	Physical	Lower Granite	- Optimize Deflectors			TBD		
Lower Snake 5	Study	Lower Granite	- New Spill Patterns			2003 – 2006 Final TBD in conjunction with RSW operations		
Lower Snake 6	Physical	Lower Granite	- Pier Nose Extensions			TBD		
Lower Snake 7	Physical	Lower Granite	- Divider Walls			TBD		
Lower Snake 8	Physical – Bio Study	Lower Granite	RSW			2003 – 2007	I	
Lower Snake 9	Bio Study	Lower Granite	Spillway Passage Survival Study			2004 – 2006	I - II	
Lower Snake 10	Gas Study	Lower Granite	Near Field Testing			2003?		
Lower Snake 11	Study – Physical - Operational	Little Goose	Gas Fast Track			2002 – TBD Not funded due to low priority by SCT		
Lower Snake 12	Study	Little Goose	- General Model Tests			TBD		

Lower Snake 13	Operational	Little Goose	- New Spill Patterns			Final Patterns TBD after RSW installation. 2005 – 2006 Interim Patterns developed to support RSW design		
Lower Snake 14	Study – Physical - Operational	Little Goose	- End Bay Deflectors			TBD	I	
Lower Snake 15	Study – Physical - Operational	Little Goose	- Optimize Deflectors			TBD		
Lower Snake 16	Study – Physical - Operational	Little Goose	- Spillway Divider Wall			TBD		
Lower Snake 17	Study – Physical - Operational	Little Goose	- Spillway Sectional Model Test			2002 – TBD Not funded due to low priority by SCT		
Lower Snake 18	Bio Study	Little Goose	- Spill Passage Survival Studies			2004 – 2006	I - II	
Lower Snake 19	Gas Test	Little Goose	- Near Field Test			TBD		
Lower Snake 20	Physical – Bio Study	Little Goose	- RSW			2009 – 2012 Currently under design with installation targeted for 2009	II	
Lower Snake 21	Study	Lower Monumental	- Physical Model Development			1999		
Lower Snake 22	Physical	Lower Monumental	- Gas Fast track			2001 - 2004		

Lower Snake 23	Physical	Lower Monumental	- End Bay deflectors			2001 – 2003	I	
Lower Snake 24	Operational	Lower Monumental	- Spill patterns			Final Patterns TBD after RSW installation. Interim Patterns 2002 - 2006		
Lower Snake 25	Physical	Lower Monumental	- Divider Wall Report			2004		
Lower Snake 26	Physical	Lower Monumental	- Relocation of Juvenile Bypass Outfall Pipe Report			2004	I	
Lower Snake 27	Physical	Lower Monumental	- Stilling Basin Repair			2001 – 2003		
Lower Snake 28	Gas Study	Lower Monumental	Near Field Test			2004		
Lower Snake 29	Bio Study	Lower Monumental	Passage/Survival			2003-2006	I - II	
Lower Snake 30	Study	Lower Monumental	Extended Fish Screens			TBD	II	
Lower Snake 31	Physical – Bio Study	Lower Monumental	RSW			2007 – 2010 Currently under construction with installation targeted for 2007	II	
Lower Snake 32	Physical	Ice Harbor	Flow Deflectors (4)			1996	I	
Lower Snake 33	Physical	Ice Harbor	Flow Deflectors (4)			1997	I	
Lower Snake 34	Physical	Ice Harbor	Flow Deflectors (2)			1999	I	
Lower Snake 35	Gas Study	Ice Harbor	Near Field Test			Not Scheduled		
Lower Snake 36	Operational	Ice Harbor	Spill Patterns			1999 – 2006 Final Patterns TBD in conjunction with RSW operations		
Lower Snake 37	Bio Study	Ice Harbor	Passage/Survival			1999 – 2005	I - II	

Lower Snake 38	Physical – Bio Study – Operat.	Ice Harbor	RSW			2005 – 2010	II	
Lower Snake 39	Phys. – Study	Ice Harbor	Divider Wall			TBD		

Table A-7 Lower Columbia River

Action Item #	Type Of Measure	Project Location	TDG Measures	Major Issues or Concerns	Lead Agency	Status/ Year(s)	TMDL IP Phase	NMFS 2000 FCRPS RPA
L Columbia 1	Document	System	Final TMDL-TDG			2002		
L Columbia 2	Physical – Operational – Study	McNary	Gas Fast Track			2002 – TBD Not funded due to low priority ranking by SCT		
L Columbia 3	Physical – Operational – Study	McNary	Gate Hoists			2002 - Unresolved		
L Columbia 4	Physical – Operational – Study	McNary	Deflector Optimization			2002		
L Columbia 5	Physical – Operational – Study	McNary	Spill Patterns			2002		
L Columbia 6	Physical – Operational – Study	McNary	Divider Walls			TBD		
L Columbia 7	Physical – Operational – Study	McNary	Training Walls			TBD		
L Columbia 8	Physical – Operational – Study	McNary	Modeling			TBD		
L Columbia 9	Physical – Operational – Study	McNary	Outfall relocation			TBD	II	
L Columbia 10	Physical – Bio Study	McNary	RSW or other Surface Passage measures			2005 - 2012		
L Columbia 11	Physical	McNary	Turbine Replacement			2008-2015		

L Columbia 12	Bio Study	McNary	Spillway Passage Survival			2003 - 2006	I - II	
L Columbia 13	Study	McNary	Near Field Test			Not Scheduled		
L Columbia 14	Physical	McNary	Endbay Deflectors			2002	I	
L Columbia 15	Physical	John Day	Flow Deflectors (18/20)			1998 – 1999	I	
L Columbia 16	Study - Physical	John Day	RSW (Surface Bypass)			Ongoing	II	
L Columbia 17	Bio Study	John Day	Passage/Survival Studies			2000-2004	I - II	
L Columbia 18	Physical	John Day	Extended Screens			2004 Decision	II	
L Columbia 19	Physical	John Day	End Bay Deflectors			TBD	I	
L Columbia 20	Physical	John Day	End Bay Deflector – Bay 1			TBD	I	
L Columbia 21	Study – Physical	The Dalles	Spillway Improvement Study			2003 – 2008	I	
L Columbia 22	Study – Physical	The Dalles	Spill Wall			2004		
L Columbia 23	Study – Physical	The Dalles	Forebay Guidance			Ongoing		
L Columbia 24	Study – Physical	The Dalles	Spillbay and Tailrace Modifications			Ongoing		
L Columbia 25	Study - Physical –	The Dalles	Surface Bypass			2003 – 2007 (On hold)		
L Columbia 26	Study – Physical	The Dalles	Turbine Intake Blocks			2000-2002 Terminated	I	
L Columbia 27	Study – Physical	The Dalles	Sluiceway Outfall relocation			2000-? On Hold	I	
L Columbia 28	Bio Study	The Dalles	Spillway and Sluiceway Survival Study			2000 – 2009	I - II	
L Columbia 29	Physical	Bonneville	Spillway Deflectors (13/18)			1970's		
L Columbia 30	Physical	Bonneville	Spillway Deflectors (18/18)			2002	I	
L Columbia 31	Study - Physical	Bonneville	PH1 improvements			Terminated	I	
L Columbia 32	Study – Physical	Bonneville	PH1 Surface Bypass			Ongoing	I	
L Columbia 33	Physical	Bonneville	PH2 Corner Collector			2004	I	

L Columbia 34	Physical Study	Bonneville	Turbine Improvements (MGRs)			Ongoing	II		
L Columbia 35	Physical	Bonneville	PH2 FGE Improvement			Underway	I		
L Columbia 36	Bio Study	Bonneville	Passage/Survival Studies			Ongoing	I - II		
L Columbia 37	Study – Physical – Operational	Bonneville	Gas Fast Track			2002			
L Columbia 38	Study	Bonneville	Near Field Testing			2002			
L Columbia 39	Physical	Bonneville	Improve Existing Deflectors if needed			Ongoing			
L Columbia 40	Operational	Bonneville	Spill Patterns			Ongoing			

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 – 2007 Monitoring Plan

To be included: Draft Final Corps of Engineers Plan of Action for Dissolved Gas Monitoring in 2007, dated October 2006.

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	Studies in Progress	In Progress	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 2002-2007	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, http://www.wrh.noaa.gov/Portland/TM239/PG46.html, 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) http://www.wrh.noaa.gov/Portland/TM239/PG65.html.

	% 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).

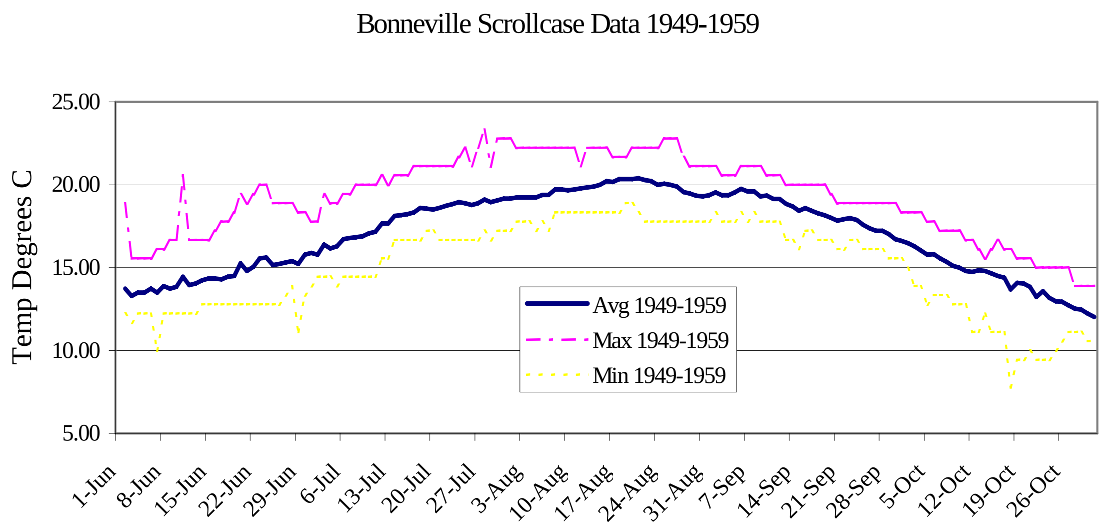

Figure 1. Maximum, minimum, and average Bonneville Dam Scrollcase temperatures 1949-1959 as reported at DART.

	% 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.

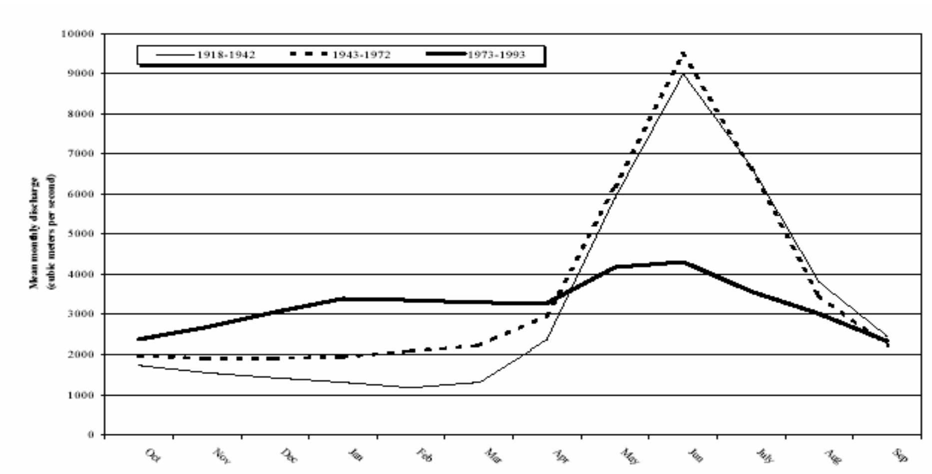

Figure 2. Columbia River Hydrograph as measured at Priest Rapids Gage. Time periods designate pre-Grand Coulee, Grand Coulee to Mica Dam, and post Mica Dam.

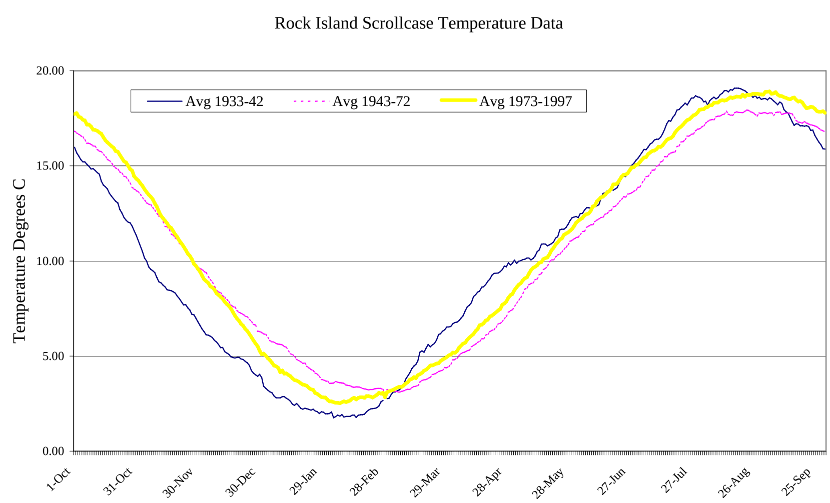

Figure 3. Columbia River average daily temperature as measured at Rock Island Dam scrollcase. Time periods designate pre-Grand Coulee, Grand Coulee to Mica Dam, and post Mica

Dam completion.