2001

CORPS OF ENGINEERS
DISSOLVED GAS AND WATER TEMPERTURE MONITORING

COLUMBIA RIVER BASIN

March 2001

Water Quality Unit
Reservoir Control Center, Water Management Division
U. S. Army Corps of Engineers North Pacific Division
Portland, Oregon

Including Material Provided by:
Portland District-US Geological Survey
Engineering Research and Development Center
Walla Walla District

And

ArsenaultLegg, Inc
1601 Abbott Road, Suite 203
Anchorage, AK 99507
Phone: (907) 346-3827
Fax: (907) 346-1577
E-mail: information@arsenaultlegg.com
Web site: www.arsenaultlegg.com

EXECUTIVE SUMMARY

Part 1 of this Annual Dissolved Gas Monitoring Program Report for 2001 provides program descriptions. Program descriptions include a section on Clean Water Act (CWA) and Endangered Species Act (ESA), monitoring station descriptions, and a reference to the detailed 2001 Plan of Action prepared for the Technical Management Team (TMT). Part 2 of the report encompasses Program Operating Conditions, including water year runoff conditions with weather, streamflow and reservoir operation subsections, and water releases including spill. Part 3 of the report summarizes Program Results. Program Results include a review of total dissolved gas.

The technical core of the report, describing the 2001 water quality, is in Part 3. Operation of the Corps of Engineers' (Corps') Columbia River Basin dams, consistent with the total dissolved gas standard for total dissolved gas, was excellent.

Water year 2001 was characterized by drought conditions. The unregulated runoff from January through July at The Dalles was 58.2 Maf, only 55% of the 1961-1990 average. The unregulated runoff during August through July operating year at The Dalles was the lowest in the 1878-2001 historic record at 82.6 Maf.

Total dissolved gas (TDG) exceedances were very few for the water year. Oregon and Washington State standards were exceeded for 5 days in the Lower Granite forebay, 6 days in the McNary forebay, and 2 days at the Camas/Washougal monitoring station during the spring/summer spill season. The exceedances were limited duration daily occurrences (the average of the12 highest values) ranging from 115 to 119 percent that were attributed to a combination of meteorological conditions and incoming conditions from upstream. Idaho State water quality standards were exceeded for 17 individual hours in the Dworshak tailwater during the entire 2001 water year.

Water temperature compliance exceedances above 68^{o}F ranged between 17 and 68 days at the monitoring sites on the Columbia River, and between 8 and 85 days at the Snake River sites, and 0 days at the Clearwater sites. Generally, the forebay sites experienced the long-term exceedances because of near-field conditions at the dams while the tailwater sites experiences the lower exceedance periods because of the more fully mixed river conditions of the tailwater. Forebay water temperatures generally peaked about 75^{o}F while the tailwater temperatures were generally near 70^{o}F at the Snake River dams. At the lower Columbia dams, McNary and John Day were the only forebay location where water temperatures peaked near 75^{o}F. The other Columbia dams experienced forebay peaks of about 72^{o}F or 73^{o}F. The lower Columbia dams experienced tailwater exceedances in the low 70^{o}F range.

Due to the low water year and limited spill thoughout the spill season, there were no chronic exceedance problems at the fixed monitoring sites (FMSs). It is interesting too note that even with little spill in the Columbia River system there were still elevated TDG levels in the Dworshak tailwater, McNary forebay, Lower Granite forebay, and at Camas/Washougal that were attributed to hot weather conditions.

2001 DISSOLVED GAS AND WATER TEMERATURE MONITORING
LOWER COLUMBIA RIVER BASIN

Table of Contents

Table of Contents (continued)

Part 1 Program Description

1.1 Clean Water Act and Endangered Species Act

1.1.1 General

The report focuses on the total dissolved gas monitoring on the Columbia River Basin. These dams are part of a larger Corps monitoring system.

There are two purposes for the Corps of Engineers (Corps) for monitoring total dissolved gas (TDG) and water temperature at ten Columbia River Basin dams: 1) to monitor project performance in relation to water quality standards, and 2) to provide water quality data for anadromous fish passage at Columbia/Snake mainstem dams. The monitoring program is considered an integral part of the Corps' Reservoir Control Center water management activities.

TDG is the primary water quality parameter monitored. 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. Both TDG and water temperature are closely linked to project water management operations (e.g. water released over the spillways, releases through the powerhouses and other facilities, and forebay and tailwater water surface elevations).

1.1.2 Corps Goals

The general policies of the Corps are summarized in the **Corps Digest of Water Resources Policies and Authorities**, Engineering Pamphlet 1165-2-1, dated February 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).

1.1.3 Biological Opinion (BiOp)

1.1.3.1 1995 and 1998 BiOps

The data from the Corps Dissolved Gas Monitoring Program before 1984 was used to voluntarily monitor for water quality standard. In 1984, the Corps Dissolved Gas Monitoring Program was enhanced to serve the dual purposes stated in 1.1.1 General.

With the listing of certain Snake River salmonids under the 1991 Endangered Species Act (ESA), 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 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 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:

TDG

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 risk of the elevated levels of TDG on migrating salmon and decided the risk 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.

Water Temperature

Water management operations to reduce water temperature in the lower Snake River for the benefit of adult Snake River fall Chinook salmon were considered. (95 BiOpIV.A.1.g, pages 44 - 45) The NMFS BiOp concluded that although the priority for cool water releases from Dworshak Dam were for migrating juvenile fall Chinook in July and August, releases to reduce water temperatures in September could be considered on an annual basis through the NMFS Forum's Technical Management Team (TMT). Incidental Take Statement # 17 of the 1995 BiOp specifically recognizes the potential releases from Dworshak Dam for water temperature control.

Incidental Take Statement # 5 of the 1995 BiOp also recognizes special operating criteria to mitigate adverse warm water conditions that periodically occur at McNary Dam in the summer.

1.1.3.2 2000 BiOp

The Final NMFS and FWS Biological Opinions states:

"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."

USFWS BiOp

According to the UFWS 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 Federal Columbia River Power System (FCRPS).

NMFS BiOp
The NMFS 2000 BiOp identified metrics that are 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 are 14 RPAs (namely, RPAs 130 to 143) identified as part of a water quality strategy in the NMFS 2000 BiOp. Specifically, RPA's 131 and 132 deal with water quality monitoring. RPA 131 indicates that the physical and biological monitoring programs are to be developed in consultation with the NMFS Forum regional Water Quality Team and the Mid-Columbia Public Utility Districts (PUDs). RPA 132 specifies that a plan must 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.

1.1.4 TDG Variance

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 variances from appropriate State water quality agencies. The Corps took the actions necessary for the 2001 spill season.

The Corps also addressed variances from the total dissolved gas water quality standard with the States and tribes impacted by the program implemented in the Federal Columbia River Power System (FCRPS) for which the Corps has responsibility. As a long-term strategy, the Corps opened discussions about the process of pursuing long-term variances from the entities involved, hoping to eventually replace the year-to-year processes. Meetings with the States and tribes were held in the spring and summer to begin discussions.

Further meetings will be held in the coming year to continue to pursue long-term variances.

In the interim, as long-term variances are being explored, the Corps pursued the following actions to obtain a variance from the State of Idaho, Oregon, and Washington.

1.1.4.1 State of Idaho

The State of Idaho was approached 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 for the 2001 water year. State water quality standards were generally met.

1.1.4.2 State of Oregon

The Corps took appropriate actions for attaining a water quality variance from the State of Oregon for the 2001 spill season. A letter was provided to the Oregon Department of Environmental Quality on February 1, 2001. The Oregon Environmental Quality Commission met on March 30, 2001 and approved a variance for the 2001 spill season, subject to specific conditions, as signed by Stephanie Hallock on May 5, 2001. A variance of the TDG standard for the Columbia River was provided from

midnight on April 10, 2001 to midnight August 31, 2001. The Commission approved a TDG standard 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 variance would be terminated.

The following conditions were incorporated into the Commission's variance. The Corps was to provide written notice to the Oregon Department of Environmental Quality on any exceedances of the conditions in the variance as it relates to voluntary spill. The Corps was to provide a written report of the spill program for 2001 by December 31, 2001 and supply information on the levels of TDG, the fish monitoring, and incidence and severity of gas bubble disease. Additionally, any proposal for a modification to the TDG standard in 2002 was to be received by the Oregon Department of Environmental Quality no later than December 31, 2001.

1.1.4.3 State of Washington

The State of Washington modified it's rule on TDG standards for multi-year to accommodate fish passage spill as called for in the NMFS Biological Opinions. The rule is in effect until 2003. Additional actions with the State were not required for the 2001 water year.

1.1.5 Operating Guidelines

The Water Quality Team of the Reservoir Control Center is responsible for monitoring the TDG and water temperature conditions in the forebays and the tailwaters of the lower Columbia River/lower Snake River dams, and selected river sites. The operational water management guidelines in Oregon are to change spill levels and, subsequently, spill patterns at the dams (daily if necessary) so that the forebays are as close to, but do not exceed, daily (12 highest hours) average of 115% TDG, and the tailwater levels are close to, but do not exceed, daily (12 highest hours) average of 120% TDG.

When these decisions are made, the water volume, water elevation (where applicable), project powerhouse and spillway characteristics (where applicable), and short- and long-term weather forecasts are evaluated.

1.2 Monitoring Stations

TDG and temperature are monitored throughout the Columbia River basin using FMSs (fixed monitoring stations). There are a total of 41 FMSs in the U. S. portion of the Columbia River basin. The U. S. Bureau of Reclamation, Chelan and Grant County PUDs maintain four stations each. Two stations are maintained by Douglas County PUD. The Corps maintained the remaining stations. Appendix A contains a map of the FMS.

1.3 Monitoring Plan of Action

The Corps prepares a dissolved gas Plan of Action each year. It is a supporting document for the NMFS Forum TMT.

The TMT is an interagency adaptive management group responsible that makes recommendations on operations for the Columbia/Snake system for the benefit of listed fish species. The 1995 BiOp called for the

establishment of a TMT to optimize passage conditions at dams for juvenile and adult anadromous salmonids. A web site description of the TMT can be found at:

http://www.nwd-wc.usace.army.mil/TMT/

The 2001 Plan of Action can be found listed under the TDG category of the Reservoir Control Center Water Quality Team page on the following web site:

http://www.nwd-wc.usace.army.mil/TMT/wqwebpage/mainpage.htm

The Monitoring Plan of Action is also attached as Appendix B. The Plan summarizes the roles and responsibilities of the Corps as they relate to dissolved gas monitoring. The Plan stipulates what to measure, how, where, and when to take the measurements and how to analyze and interpret the resulting data. The Plan also provides for periodic review and alteration or redirection of efforts when monitoring results and/or new information from other sources justifies a change. The Plan identifies channels of communications with other cooperating agencies and interested parties.

Part 2 Program Operating Conditions

2.1 Water Year Runoff Conditions

2.1.1 Weather

October 2000, at the beginning of the water year, was the last month of calendar year 2000 with near average to above average precipitation. The Columbia River above Grand Coulee had 96% of average precipitation; the Snake River above Ice Harbor had 198% of average precipitation; and the Columbia River above The Dalles had 118% of average precipitation.

In November the precipitation in the region changed dramatically when only weak weather fronts moved into the basin. Precipitation was only 43%, 48%, and 49% of normal at Grand Coulee, Ice Harbor, and The Dalles, respectively. November also brought some record low temperatures in the southern basins.

A weather pattern of split flow continued in December 2000 and high pressure aloft dominated the Basin. Only a few weak storms broke through and offered little contributory precipitation. Precipitation averaged 63% of normal at the Columbia River above Grand Coulee; 55% of normal at the Snake River above Ice Harbor; and 57% of normal at the Columbia River above The Dalles. Temperatures averaged below normal for the month of December, which was punctuated with an arctic cold snap on December 11 and 12.

With little change in the upper air pattern from November and December, precipitation continued below normal in January 2001. Weak weather disturbances managed to either drift into British Columbia or cut across the far southern U. S. districts en route toward the Desert Southwest. Regional temperatures were above normal due to the absence of the cool northerly flow aloft. Precipitation was 36% of normal at the Columbia River above Grand Coulee; 51% of normal on the Snake River above Ice Harbor; and 40% of normal at the Columbia River above The Dalles.

In February temperatures and precipitation were below normal. Precipitation averaged 55% of normal at the Columbia River above Grand Coulee and at the Snake River above Ice Harbor; 51% of normal at the Columbia River above The Dalles.

By March 2001 the weather pattern continued

with a split flow, but some stronger storms managed to stay together through the northern branch of the split. Some frequent precipitation came into Canada and the northern U. S. Precipitation averaged 84% of normal at the Columbia River above Grand Coulee; 71% of normal at Snake River above Ice Harbor; and 82% of normal at the Columbia River above The Dalles.

Finally, by April 2001, more storms were able to penetrate the basin as the split flow pattern consolidated.

The wet pattern of April continued into early May 2001 as a few storms managed to keep active along the northern branch of the split flow. Consequently, these storms brought precipitation to the northern basins. This storm track dissolved mid to late in the month. Regional temperatures averaged above normal, and temperature records were broken: 95 ^{o}F at Portland, Oregon, and Boise, Idaho, 100 ^{o}F at Medford, Oregon, and 92 ^{o}F at Pocatello, Idaho. May precipitation averaged 59% of normal at the Columbia River above Grand Coulee; 48% of normal on the Snake River above Ice Harbor; and 62% of normal on the Columbia River above The Dalles.

Below normal temperatures and above normal precipitation covered most of the Basin in early June 2001. A westerly flow aloft brought the most frequent storms across the northern basins, while the southern basins remained dry. Precipitation for June was 117% of normal at the Columbia River above Grand Coulee; 65% of normal at the Snake River above Ice Harbor; and 99% of normal at Columbia above The Dalles.

In July 2001, onshore flow governed by offshore upper level low pressure brought above normal precipitation to much of the Basin while keeping temperatures slightly below normal region-wide. Precipitation averages for the month of July included 102% of normal at the Columbia River above Grand Coulee; 118% of normal at the Snake River above Ice Harbor; and 103% of normal at the Columbia River above The Dalles.

The offshore low pressure moved west and was replaced with upper level high pressure as the split flow aloft regained footing during August 2001. Although a sub-tropically fed storm brought above normal precipitation totals to part of British Columbia and areas west of the Cascades, precipitation was mainly below normal even with this active weather system. For August, precipitation was 32% of normal at the Columbia River above Grand Coulee; 20% of normal at the Snake River above Ice Harbor; and 32% of normal at the Columbia River above The Dalles.

2.1.2 Streamflow

The January 1, 2001 water supply forecast for the Columbia River at the Dalles (January-July) was 80.4 Maf, or 76% of the 1961-90 average. Precipitation was very low through March, with monthly average precipitation spiking in April, sagging in May, and rising to near-normal in June and July. The water supply gradually declined over the period, finally leveling off in June and July. The unregulated runoff from January through July was 58.2 Maf at The Dalles, only 55% of the 1961-90 average. The actual unregulated runoff during the August through July operating year at The Dalles was the lowest in the 1878-2001 historic record at 82.6 Maf. The timing of the runoff in 2001 was about average, with the peak-unregulated flow at The Dalles occurring in late May. The observed peak unregulated flow at The Dalles was 326,800 cubic feet per second (cfs) on May 30, 2001.

The Columbia River was operated to meet Chum salmon needs below Bonneville Dam and meet power demands from November 2000 through March 16, 2001. During this time, the Regional Executives of Federal, State and tribal agencies were active in setting operating priorities and criteria. By April the operating strategy was

shifted to refilling storage projects as much as possible, where Dworshak was the top priority for refill by June 30, 2001. The Dworshak reservoir was drafted to 80 feet from full by August 31 for flow augmentation and temperature control in the lower Snake River.

Composite operating year unregulated (natural) streamflows in the basin above The Dalles were below normal, and about 31% below last year's average streamflows. These calculated flows have been corrected to exclude the effects of regulation provided by storage reservoirs. May was the high month during the spring runoff, being in the range of 68% of normal. The August 2000 through July 2001 runoff for The Dalles was 82.6 Maf, 78% of the 1961-90 average, and the lowest on record for the period 1928 through 2001. The peak regulated discharge for the Columbia River at The Dalles was 326,800 cfs on May 30, 2001. The 2000-01 monthly-unregulated (natural) streamflows and their percentage of the 1961-90 average monthly flows are shown in the following table for the Columbia River at Grand Coulee and The Dalles. These flows have been corrected to exclude the effects of regulation provided by storage reservoirs.

	Columbia River at Grand Coulee (cfs)		**Columbia River at The Dalles (cfs)**	
Time Period	**Natural Flow**	**Percent of Average**	**Natural Flow**	**Percent of Average**
Aug 00	91,741	88	115,160	84
Sep 00	58,516	91	88,144	92
Oct 00	42,349	88	78,763	92
Nov 00	30,266	62	62,482	68
Dec 00	24,688	58	57,279	61
Jan 01	25,549	62	53,701	55
Feb 01	21,589	46	53,765	46
Mar 01	29,046	49	76,177	54
Apr 01	53,206	46	111,150	50
May 01	189,938	72	287,501	68
Jun 01	174,288	53	230,166	46
Jul 01	123,844	65	150,061	58
Operating Period Average	72,424	64	114,086	78

2.1.3 Reservoir Operation

2.1.3.1 General

The 2001 operating water year began with normal to slightly above normal precipitation, however, by November the basin became dry and snowpack was not building. Although the first official water supply forecast prepared in January 2001 by the National Weather Service River Forecast Center was 76% of average (80.4 Maf for the January through July period) for the period 1961-1990, each successive months' final water supply forecast diminished. By April 2001, the water supply forecast was at 53% of average (56.1 Maf for the January through July period).

By the end of April many reservoirs in the U.S. had been drafted very deeply to meet U.S. power needs through the winter. The river system was being operated to maintain a minimum tailwater elevation at Bonneville Dam from November through April for listed Chum downstream of Bonneville Dam. Canadian reservoirs also had drafted deeply to meet power needs.

The winter of 2000-2001 was very dry and was characterized by low natural streamflow. By early December 2000 the U.S. was using water in storage to maintain a flow of 140 thousands of cubic feet per second (kcfs) at Bonneville Dam to keep the Chum spawning area downstream of Bonneville Dam wet. Once the Chum are in the area and have spawned attempts should be made

to maintain a steady flow so that the redds (fish eggs) which have been deposited, are not de-watered, allowing the fish fry to emerge in May.

In mid-December the Pacific Northwest experienced a short duration cold snap, where water from the Federal reservoirs was used to meet the regional power demands.

In January, as streamflow remained low, the Bonneville Power Administration (BPA) established a longer duration power emergency where Federal reservoirs were again drafted to meet regional power needs. In April 2001, BPA declared another power emergency. The power emergency declaration superceded the Corps' ability to spill up to the full amounts recommended in the NMFS 2000 BiOp.

The final observed runoff at The Dalles for the period January thorough July 2001 was 58.2 Maf, 55% of average. This is the second lowest for the period since 1928. Because this was slightly greater than the April through June water supply forecasts, the Corps was able to spill some water in August to help listed juvenile fish migration.

Both the NMFS and the USFWS issued final BiOps on December 2, 2000. These BiOps cover all fish species and encompass all the previous supplements to the 1995 BiOps.

The 2000 BiOps have similar operational provisions as the previous BiOps and BiOp Supplements. These provisions include seasonal flow objectives at certain dams, which are based on a sliding scale water supply forecast:

- Lower Granite, 85,000-1000,000 cfs during 10 April – 20 June, and 50,000-55,000 cfs during 21 June-31 August.
- McNary, 220,000-260,000 cfs during 20 April – 30 June, and 200,000 cfs during 1 July 31 August.
- Priest Rapids, 135,000 cfs during 3 April through 20 June. (This objective does not vary with water supply.)

The NMFS BiOp also recommends that Federal projects be at the April 10 flood control elevation by that date and be full on June 30. The projects may then be drafted in July and August for summer flow augmentation.

Due to the extreme low water conditions in the spring of 2001 and the use of water earlier in the season for power and Chum operations, the Federal projects were well below April 10 flood control elevations. None of the Federal projects were able to refill by June 30. All projects were evacuated to their draft limits in the 2001 summer flow augmentation period.

2.1.3.2 Flood Control

The Columbia River Basin reservoir system, including the Columbia River Treaty projects, were not operated for flood control during the 2000 - 2001 winter period, since the weekly agreed-upon operations were adequate to accomplish spring flood evacuation control goals. The weekly operation was guided, to a large extent, by the daily streamflow and reservoir simulations and to a lesser degree by the guidance on charts in the Flood Control Operating Plan. Due to a near record low runoff, flood control was not an issue. The unregulated peak flow at The Dalles, Oregon is estimated at 326,800 cfs on May 30 and a regulated flow of 169,400 cfs on May 17. The unregulated stage at Vancouver, Washington was 10.5 feet on May 31 and the high-observed stage was 5.5 feet on June 1.

2.2 Water Releases

2.2.1 Spill

2.2.1.1 Spill During Drought

Low river volumes and power emergencies characterized the 2001 spill program. The

following table indicates how many hours of spill there was at each mainstem project during the spring and summer spill season. The table also includes the percent of hours during which there was spill.

Project	Spill Season (4032 – 4560 hours)	Spill (Hours)	Spill (%)
Lower Granite	Apr 1 – Sep 15	39	<1
Little Goose	Apr 1 – Sep 15	3	<0.5
Lower Monumental	Apr 1 – Sep 15	36	<1
Ice Harbor	Apr 1 – Sep 15	7	<0.5
McNary	Apr 1 – Sep 15	142	3.5
John Day	Apr 1 – Sep 15	274	6.8
The Dalles	Apr 1 – Sep 15	1643	40.7
Bonneville	Mar 10 – Sep 15	1746	38.3

Spring Spill
The 2000 BiOp states that if the flow in the Snake River is less than 85 kcfs then no spill will occur at these Snake River collector projects and fish transport will be maximized. Following this BiOp guidance, there was no voluntary spill for juvenile fish passage at the Snake River projects. What little spill there was due to other reasons (testing, mechanical problems).

The rationale for determining which Columbia River projects to spill at and in what order are outlined in the NMFS regional forum TMT documents contained on the following web site:

http://www.nwd-wc.usace.army.mil/TMT/

The spring spill program started May 16 and ended on June 15 for The Dalles and Bonneville Dams. Fifty (50) kcfs was spilled at Bonneville Dam 24 hours a day. Thirty (30) percent of the river was spilled at the Dalles Dam 24 hours a day.

Spring spill started on May 25 for the John Day and McNary Dams. At John Day, 30% of the total river flow was spilled during nighttime hours. At McNary 30 kcfs of the total river flow was spilled every other night. Spill continued at John Day and McNary Dams until June 15.

Due to the California and Northwest power emergency issues, the spring spill program was limited to an amount of water that would have been used to generate 600-megawatt months of power. The 600-megawatt months was agreed to through negotiation in the NMFS Regional Forum TMT meetings and Regional Executive meetings. This figure was largely based on recommendations from the BPA in terms of meeting load during the power system emergencies.

Summer Spill
The Summer Spill Program was characterized by low river flows and Northwest Regional Power Emergency and Power System Reliability issues. (Refer to the TMT meeting notes for the summer months.)

Summer spill began on July 24 at Bonneville and the Dalles Dams. Adjustments were made to the spill levels in early August. Summer spill was discontinued on August 31.

2.2.1.2 Voluntary and Involuntary Spill

Within the Columbia River Basin there is an interest in correlating TDG standard exceedances and times of involuntary spill at the projects. Appendix C contains the spill at the lower Columbia River projects.

As defined in the May 2001 Corps Record of Consultation and Statement of Decision (page c-4), voluntary spill is spill for juvenile fish passage and flow augmentation. Involuntary spill is that portion of the total river flow, which must pass over a dam's spillway when the dam's

powerhouse hydraulic capacity is exceeded. The hydraulic capacities of the powerhouses were not exceeded in 2001.

2.2.2 Dworshak Releases

During the mid to late summer, water releases from Dworshak Dam were adjusted and used to cool the lower Snake River.

Appendix D contains graphs showing water temperatures at the Anatone, Lower Granite Dam forebay, and Lower Granite tailwater FMSs. The benefit of the cold-water releases can be seen in the Lower Granite tailwater temperature monitoring. The Lower Granite tailwater daily average water temperature exceeded the State standard of 68°F by up to 1.4 degrees for eight days during the spill season.

Targeting low temperature water to provide cooling effects in the Snake River, flow augmentation from Dworshak Dam began on July 2, 2001. A review of the graphs in Appendix D shows an immediate drop in river temperature at the Lower Granite tailwater from above 68°F to below the State standard.

In the 2001 water year, the Corps Walla Walla District collected tri-level thermograph data in the Lower Granite forebay. Review of the data by the Walla Walla District indicates that the Lower Granite forebay water column stratified to a greater degree than is typically seen in a “normal” water year. The tri-level thermograph data is available from the Walla Walla District.

In water year 2000, due to less stratification of the Lower Granite forebay, the benefit of the cold-water releases could be viewed by comparing the Anatone and Lower Granite forebay temperatures. The temperature benefit in the Lower Granite forebay in 2001 was masked by the reservoir stratification.

The water temperature in the Snake River appears to be dominated by air temperature, however, some moderation of air and solar heating can be affected by the release of cool water from the Dworshak Reservoir.

Reviewing the Lower Granite tailwater temperature the benefit of the cold-water releases from Dworshak can be seen. The Lower Granite tailwater temperature daily average exceeded 68°F for only eight days during the spill season. The Lower Granite forebay temperature daily average exceeded 68°F for 85 days during the same period. The differences in the number of exceedances between the tailwater and the forebay is attributed to the turbine penstocks drawing water from below the water surface with some mixing of the localized, stratified water column.

2.2.3 MASS1 Numerical Modeling

The Corps used a numerical model called Modular Aquatic Simulation System (MASS1) to provide water temperature technical information to the NMFS Forum TMT for their consideration of various water management scenarios related to reservoir operations during the 2001 drought conditions. Additionally, the Environmental Protection Agency (EPA) also provided TMT with water temperature modeling information using EPA's River Basin Model (RBM10).

MASS1 is a one-dimensional, unsteady hydrodynamic and water quality numerical model developed by Battelle Pacific Northwest National Laboratory (PNNL). It was the major numerical modeling tool for the Corps Dissolved Gas Abatement Study (DGAS) of the Columbia/Snake Rivers in the late 1990s and early 2000s. As part of the DGAS effort, TDG and water temperature were simulated for approximately 800 miles of the lower Columbia and Snake rivers, including 15 hydroelectric projects. The model was calibrated for water temperature and TDG transport using in-stream monitoring data from 1996 and 1997.

In 2001, MASS1 was used to provide TMT with comparative information about the magnitude of the high water temperatures that *could* occur during hot summers, with high air temperatures and very low river flows. It is important to note that the model was not used to forecast 2001 summer water temperatures in the Columbia/Snake system. A forecasting effort would have necessitated forecasting system-wide meteorology and hydrology, and that was currently beyond the capability of MASS1. However, the model was used to provide comparative information.

During the spring of 2001, EPA noted that the highest water temperatures that have occurring in the lower Columbia/Snake Rivers, under the current mode of system operation was in 1994. The National Weather Service River Forecast Center indicated that the lowest flows, with the present number of storage and run-of-river dams, in the Columbia River Basin were in 1977.

The Corps, therefore, had PNNL first model 1977 river flows with 1977 water temperatures to verify that the model results would be similar to the actual 1977 water temperatures. Subsequently, the Corps had PNNL model several scenarios using varying volumes of cool water from Dworshak Dam in Idaho to cool the lower Snake River system. The scenarios used low-flow 1977 hydrology with hot the 1994 summer meteorological conditions to evaluate the relative magnitude of the water temperature during the summer and early fall, especially at Lower Granite Dam in the lower Snake River. The scenarios varied Dworshak release flows, using the record-low system river flows and the record water temperatures. The results of the scenario modeling were shown to TMT as technical information to assist them in establishing Dworshak summer flow releases.

The entire PNNL report can be viewed at the following web site:

http://www.nwd-wc.usace.army.mil/TMT/wqwebpage/mainpage.htm

Examples of the scenario results at Lower Granite Dam, compared to actual 2001 water temperatures, are shown in Appendix D. The total flow of the 2001 water year was slightly greater than 1977 and the 2001 summer meteorological conditions were cooler than 1994. Despite the differences between the actual 2001 conditions and the modeled hydrology and meteorology, the comparative results were very good. It appears that, during the 2001 drought conditions, the one-dimensional model best provided comparative information concerning the tailwater temperatures at the dams. The actual solar heating that occurred in the river during drought conditions seems to have had the most affect on the forebay water temperatures immediately upstream of the dams, causing some vertical water temperature stratification in the water column. Therefore, a comparison with the actual 2001 forebay water temperatures indicates that modeled water temperatures (one-dimensional values with no reference to forebay or tailwater) were cooler than the actual forebay water temperatures. It should be pointed out that a one-dimensional model does not address vertical stratification in a water column, therefore, the MASS1 model performed very well when used in a comparative mode for 2001 conditions.

Part 3 Program Results

3.1 Water Quality Review

3.1.1 Total Dissolved Gas

The NMFS 1995, 1998, and 2000 BiOp spill program was implemented to comply with the State water quality standards variances. During the spill season the TDG level in the project

forebays and tailwaters was monitored. Adjustments, when necessary, were made to the upstream project spill levels to maintain the average of the 12 highest values in 24 hours in project forebays at less than 115% TDG and the average of the 12 highest values in 24 hours in project tailwaters at less than 120%.

Appendix E contains a listing of the maximum and minimum TDG values measured at each FMS for each month of the spill season as well as the number of hours and days the TDG standards were exceeded each month.

Idaho State standards were exceeded for seventeen hours at Dworshak during the water year with only 2 hours of exceedance during the summer spill period. This performance is consistent with the fact that no spill occurred at Dworshak Dam during the 2001 water year. The releases through the Dworshak Dam powerhouse were monitored and maintained at levels that would not generate TDG above the State standard.

Washington and Oregon State standards during the spill season exceeded five times in the Lower Granite forebay (August) and six times in the McNary forebay (April and May). The exceedances of the TDG variance standards in the forebays are ascribed to incoming conditions from upstream as well as to atmospheric temperature affects. The exceedance occurrence of the highest 12 values in a 24 hour period were of short duration, of a day or a few days, ranging between 115 and 119 percent. Refer to Appendix K for the Walla Walla District TDG Report discussion of the sites above.

State standards were exceeded twice at the Camas/Washougal station. These exceedances occurred during May. Refer to Appendix I for the U. S. Geological Survey (USGS) discussion of the Camas/Washougal site.

Due to the low water year and the lack of voluntary spill at most projects for most of the spill season, State water quality standards were met.

3.1.2 Water Temperature

The states' water quality standards for temperature are 68°F or higher with more specific criteria about how much the temperature can increase due to human actions when the river temperature exceeds 68°F.

The NMFS 1995, 1998, and 2000 BiOps call for cold-water releases from Dworshak reservoir. These releases are to reduce and/or maintain cooler water temperatures in the Snake River in the July and August timeframe when ambient conditions would typically cause the temperature to rise above 68°F.

Appendix E contains a summary of the first and last hour the temperature at each station was equal to or greater than 68°F during the spill season as well as the first and last day the 24-hour average temperature was equal to or greater than 68°F during the spill season. The table also contains the number of days where at least one hourly reading was equal to or greater than 68°F and the number of days the 24-hour average was equal to or greater than 68°F.

Water temperature exceedances above 68ºF ranged between 17 and 68 days at the monitoring sites on the Columbia River, and between 8 and 85 days at the Snake River sites, and 0 days at the Clearwater sites. Generally, the forebay sites experienced the long-term exceedances because of near-field conditions at the dams while the tailwater sites experiences the lower exceedance periods because of the more fully mixed river conditions of the tailwater. Forebay water temperatures generally peaked about 75ºF while the tailwater temperatures were generally near 70 ºF at the Snake River dams. At the lower Columbia dams, McNary and John Day were the only forebay location where water temperatures peaked near 75 ºF. The other Columbia dams

experienced forebay peaks of about 72 °F or 73 °F. The lower Columbia dams experienced tailwater exceedances in the low 70 °F range.

3.1.3 Chronic Exceedance Problems

Due to the low water year and limited spill at the projects there were no chronic exceedance problems in the mainstem Snake and Columbia Rivers.

Areas of interest during this somewhat unique water year include McNary and Camas/Washougal. These were the only sites that exhibited TDG levels above State standards.

3.1.3.1 McNary

The McNary forebay is at the confluence of the Snake and Columbia Rivers and receives waters that have not been fully mixed. The Oregon forebay site tends to respond more quickly to solar heating with a corresponding increase in TDG.

During the 2001 summer spill season the Corps began studies of placing mixers in the water near the Oregon shore in an attempt to limit localized solar heating. These studies will be on going in the coming years with status reports being provided to the TMT and Water Quality Team forums. The results of the analyses of the mixer data will be considered during the fixed monitoring station system wide review.

3.1.3.2 Camas

The Camas FMS represents a theoretical forebay site in the lowest reach of the Columbia River, a site that is influenced by tidal interaction. Tidal interaction probably influenced the travel time of parcels of water spilled over Bonneville Dam. Typically the travel time was 12 to 15 hours.

This site was also significantly affected by environmental conditions such as changes in barometric pressures and changes in daily solar radiation and resulting water temperatures.

In efforts to further understand the water chemistry at the Camas/Washougal site, the USGS collected dissolved oxygen data. The USGS Report is included as Appendix I. Concerning the Camas/Washougal station, in part the report states

> "…the diurnal variations in TDG were probably due to the production of oxygen by aquatic plants and to natural temperature variations, and not due to the spill operations of the upstream dams."

3.1.3.3 Compensation depth

There was one FMS in the lower Columbia River, Warrendale that could be characterized as being shallow for portions of the spring/summer monitoring season. It was Warrendale. Appendix F contains a graph of the gage depth at Warrendale with the calculated compensation depth.

The gage depth was measured at the Warrendale site throughout the season. This FMS was above the compensation depth for ~800 hours during the spill season.

When the TDG is measured in the water column above the calculated compensation depth the TDG measured may be biased low, the actual TDG may be higher than the reading measured due to degassing.

The Peck and Lewiston sites did not have depth probes installed during 2001. Peck monitoring station on the Clearwater River broke on August 28, 2001. The water became too shallow for the Lewiston monitoring station on the Clearwater River on September 4, 2001. Readings prior to these dates at these stations should be viewed with caution and reviewed with river stage information to determine if the gages were deep enough in the water column to be below the

calculated compensation depth for the measurement of TDG.

3.2 TDG Monitoring Results

3.2.1 TDG – Average of the high 12 values in 24 hours

Consistency with State water quality standards for TDG in Oregon and Washington is based on the calculation of the average of the 12 highest values in a 24-hour period.

Appendix G contains charts of the calculated TDG values for each monitoring station for the 2001 spill season. The charts also include representation of the applicable standard (Oregon and Washington forebays at 115% or tailwaters at 120%).

There were 13 exceedances, 5 days in Lower Granite forebay, 6 days in the McNary forebay and 2 days at the Camas/Washougal monitoring station during the spring/summer spill season. The exceedance occurrences of the highest 12 values in a 24 hour period were of short duration, of a day or a few days, ranging between 115 and 119 percent.

It is interesting to note that with almost no spill in the system, there were still some elevated TDG levels due to water temperature fluctuations. Appendix H contains charts of the hourly temperature data for the monitoring season.

3.2.2 TDG – Hourly flow, spill, and TDG

Supersaturated water is a result of spill operations at the projects. The charts contained in Appendix C represent the hourly flow, spill, and TDG data for each monitoring station. These charts show the relationship between elevated TDG levels and spill.

The Skamania graph is a good representation of the relationship between spill and TDG. During late July and early August, operations at the project were varying between 0 kcfs spill and 56 kcfs spill. The TDG fluctuations directly track the changes in spill.

Part 4 Fish Passage Summary

4.1 Biological Monitoring

The Action Agencies (Corps of Engineers, Bonneville Power Administration, and Bureau of Reclamation) are responsible for managing the FCRPS under the Endangered Species Act Biological Opinions.

Near-term TDG improvements such as spill deflectors may have little effect on reducing tailwater TDG levels since the benefits they provide will be expressed in terms of additional spill amounts to attain higher project passage juvenile survival levels and therefore, progress in species survival. As new fish passage facilities are completed and evaluated, their contribution to the attainment of hydrosystem performance standards will allow spill levels, and TDG levels, to be reduced.

The spill cap levels recognized in the 2000 Biological Opinion, and consistent with state and tribal water quality variances, are: a daily average (based on the12 highest hours) of 115 percent in the project forebays, a daily average (based on the 12 highest hours) of 120 percent in the project tailwaters, and a maximum high 2-hour average of 125 percent anywhere in the river. The criteria replace the 80 percent fish passage efficiency criteria of the 1995 Biological Opinion.

Simpass numerical model information from NMFS concerning an estimate of the difference

in 2001 salmon survival due to the issuance of a TDG standard variance from 110 percent to 120 percent in the tailwaters of the dams in lower Columbia River is shown in Appendix J. Cumulative dam survival was increased by 9.2 percent for steelhead, 7.9 percent for yearling chinook, and 5.0 percent for subyearling chinook.