US Army Corps of Engineers
Northwestern Division

2004 DISSOLVED GAS AND WATER TEMPERATURE MONITORING REPORT

COLUMBIA RIVER BASIN

The Dalles Dam

Columbia Basin Water Management Division
Reservoir Control Center
Water Quality Unit

December 2004

DEPARTMENT OF THE ARMY
NORTHWESTERN DIVISION, CORPS OF ENGINEERS
P.O. BOX 2870
PORTLAND, OREGON 97208-2870

Reply to
Attention of:

DEC 21 2004

Columbia Basin Water Management Division

Dear Interested Party,

Enclosed is the U.S. Army Corps of Engineers (Corps) 2004 Dissolved Gas and Temperature Monitoring Report, Columbia River Basin. It was prepared to describe operation of the Corps' mainstem projects on the Columbia and lower Snake River and reports on total dissolved gas and water temperature for 2004.

Please contact Mr. James Adams at (503) 808-3938 if you have any questions or comments.

Sincerely,

Cynthia A. Henriksen
Chief, Reservoir Control Center

2004

U.S. ARMY CORPS OF ENGINEERS
DISSOLVED GAS AND WATER TEMPERTURE MONITORING REPORT

COLUMBIA RIVER BASIN

December 2004

Water Quality Unit
Reservoir Control Center, Columbia Basin Water Management Division
U. S. Army Corps of Engineers Northwestern Division
Portland, Oregon

Including Material Provided by:
Portland District-U.S. Geological Survey (Portland Office)
Walla Walla District – U.S. Geological Survey (Pasco Office)
Seattle District – Columbia Basin Environmental.
Corps of Engineers' Engineering Research and Development Center
Fish Passage Center

2004 DISSOLVED GAS AND WATER TEMERATURE MONITORING COLUMBIA RIVER BASIN

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List of Acronyms

The following acronyms are used throughout this report.

BiOp = Biological Opinion
Cfs = cubic feet per second
Corps = US Army Corps of Engineers
CRT = Columbia River Treaty
ESA = Endangered Species Act
FCRPS = Federal Columbia River Power System
FMS = fixed monitoring station
FPE = Fish Passage Efficiency
FPP = Fish Passage Plan
Kcfs = thousand cubic feet per second
Maf = Million acre feet
NMFS = National Marine Fisheries Service
NOAA Fisheries = National Oceanic and Atmospheric Agency, Fisheries (Formerly NMFS)
PUDs = Public Utility Districts
RO = regulating outlet
ROCASOD = Record of Consultation and Summary Decision
ROD = Record of Decision
RPA = Reasonable and Prudent Alternative listed in the Biological Opinion
RSW = removable spillway weir
TDG = total dissolved gas
TMT = Technical Management Team
TMDLs = Total Daily Maximum Loads
USF&WS = United States Fish and Wildlife Service
VARQ = Variable Q which means a variable flow associated with Libby flood control
WDOE Washington Department of Ecology

Terminology

The Corps has noted different agencies applying various definitions to common terminology. The following are the Corps definitions, which are used throughout this report and the 2004 Water Management Plan.

Voluntary Spill: Passing water through a project (either over the spillway or through regulating outlets (RO's)) to assist juvenile salmon passage past dam projects in the Lower Columbia and Lower Snake rivers. Voluntary spill is done to decrease the residence time of juvenile salmon in the forebay of dams, which increases their passage and survival in the FCRPS. Spill, as a fish passage strategy, has a higher survival rate than most other routes of passage at the dam. The amount of voluntary spill is adjusted so that the resulting TDG levels associated with spill are consistent with applicable State water quality criteria.

Another reason for voluntary spill is for flow augmentation. The National Marine Fisheries Service (NMFS) and United States Fish and Wildlife Service (USF&WS) BiOps call for flow augmentation in the Columbia and Snake rivers. There are instances where spill at some projects is required to obtain the flow objectives called for in these BiOps.

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

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

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

Other causes for involuntary spill include management of reservoirs for flood control, scheduled or unscheduled turbine unit outages of various durations, passing debris, or any other operational and/or maintenance activities required to manage project facilities. For example, in managing the project for flood control, the water supply forecast may underestimate the seasonal streamflows and cause the project operators to leave too little space in the reservoirs to catch the water. In other instances, unusually high winter precipitation may force the operators to store water in the reservoirs above the flood control elevations, causing involuntary spill to occur later as the water is evacuated to get to the reservoir flood control elevations.

Intertie Line Derating: The intertie line is the transmission system that transfers electricity between the Pacific Northwest and California. It is derated when its ability to transfer the electricity is decreased due to stability, thermal or environmental factors.

Unit Outage: A unit outage is a period of time when a generating unit cannot be in operation because of maintenance or repairs.

Lack of Load: There is a lack of customer need for power resulting in a lack of market for electricity generated.

TMT: An interagency technical group responsible for making recommendations on dam and reservoir operations. This group is comprised of representatives from five U.S. Federal agencies (Bonneville Power Administration; US Bureau of Reclamation; NOAA Fisheries; US Army Corps of Engineers; and US Fish and Wildlife Service) and four states (Idaho, Montana, Oregon, and Washington).

Part 1 Program Description

1.1. Clean Water Act and Endangered Species Act

1.1.1 General

This report describes the Corps' Columbia River Basin Water Quality Monitoring Program for 2004 and was developed to meet the Corps water quality program responsibilities. The report provides information consistent with the total dissolved gas variance issued by the state of Oregon and the rule modification by the state of Washington, meeting the objectives of the NOAA Fisheries Biological Opinion.

The report focuses on the water quality monitoring of total dissolved gas (TDG) and temperature at the 12 US Army Corps of Engineers (Corps) dams in the Columbia River Basin (which includes Bonneville, The Dalles, John Day, McNary, Chief Joseph, Albeni Falls, Libby, Ice Harbor, Lower Monumental, Little Goose, Lower Granite and Dworshak).

The Corps' water quality monitoring program at these dams performs two functions:

1. Monitor project performance in relation to water quality standards,
2. Provide water quality data for anadromous fish passage at Columbia/Snake mainstem dams.

The monitoring performed by the Corps is part of a larger interagency water quality monitoring system operated by the Corps that also includes the US Bureau of Reclamation monitoring system, and the Washington Public Utility District monitoring systems (as conducted by Chelan County Public Utility District, the Public Utility District of Douglas County, and the Grant County Public Utility District).

The monitoring program is considered an integral part of the Corps' Reservoir Control Center water management activities. TDG and water temperature are the primary water quality parameters monitored in the mainstem Columbia and Snake rivers in the states of Idaho, Montana, Oregon and Washington. Both TDG and water temperature may be influenced by project 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).

1.1.2 Corps Goals

The Corps policy is to comply with water quality standards to the extent practicable regarding nationwide operation of water resources projects. The general policies of the Corps are summarized in the **Corps Digest of Water Resources Policies and Authorities**, Engineering Pamphlet 1165-2-1, dated 30 July 1999. Section 18-3.b, page 18-5 of this document reads,

> "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."

1.1.3 Biological Opinion (BiOp)

1.1.3.1 Background

The data from the Corps Dissolved Gas Monitoring Program before 1984 was used to monitor consistency with water quality standards. In 1984, the Corps Dissolved Gas Monitoring Program was enhanced to serve the dual purposes stated in Section 1.1.1.

With the listing of certain Snake River salmonids in 1991 under the Endangered Species Act (ESA), the Corps implemented a variety of operational and structural measures to improve the survival of listed stocks. The 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.

Water management operations to reduce water temperature in the lower Snake River for the benefit of adult Snake River fall Chinook salmon were also considered. The NMFS BiOps 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 Regional Forum Process.

1.1.3.2 NOAA Fisheries and USF&W Biological Opinion

The Final 2000 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 2000 BiOp
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 Federal Columbia River Power System (FCRPS).

NOAA Fisheries 2000 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 actions (RPAs 130 to 143) identified as part of a water quality strategy in the NMFS 2000 BiOp. Specifically, RPA actions 131 and 132 deals with water quality monitoring. RPA action 131 indicates 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 action 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.

In response to the court remand of the NOAA Fisheries *2000 Federal Columbia River Power System Biological Opinion* under *National Wildlife Federation vs. National Marine Fisheries Service*, NOAA Fisheries prepared a Final Biological Opinions in November 30 2004. The Corps, Bonneville Power, and the Bureau of Reclamation submitted a Final Updated Proposed Action (UPA) in November 2004, which incorporated the water quality actions called for in the 2000 BiOp including a Water Quality Plan. The Final BiOp and UPA were refined in response to comments received on NOAA Fisheries' draft Biological Opinion.

1.1.4 TDG Standards

State of Idaho:
IDAPA 58.01.02-250: Surface water Quality Criteria for Aquatic Life Use Designations. 01(b): The total concentration of dissolved gas not exceeding one hundred and ten percent (110%) of saturation at atmospheric pressure at the point of sample collection.

State of Montana:
ARM 17.30.637(9): No pollutants may be discharged and no activities may be conducted which, either alone or in combination with other wastes or activities, result in the total dissolved gas pressure relative to the water surface exceeding 110% of saturation.

State of Oregon:

OAR 340-041-0031(2): Total Dissolved Gas. 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.

In a letter to the Oregon Department of Environmental Quality (ODEQ) dated December 28th, 2002, the Corps of Engineers requested a variance to the State's water quality standard for dissolved gas. In response to this request, the Oregon Environmental Quality Commission (OEQC) met on March 11th, 2003 met to consider this request, justification, and public comment. At this meeting, the OEQC approved, under Oregon Administrative Rules (OAR) 340-41-205, 445, 485, and 525(2)(n) [340-041-0061 and 340-041-0104 under current OAR's], a modification to the Total Dissolved Gas standard for spill over McNary, John Day, The Dalles, and Bonneville dams on the Lower Columbia River subject to the following conditions:

(i) a revised total dissolved gas standard for the Columbia River for the period from midnight on April 1 to midnight on August 31;

(ii) the revised criteria will apply for 2003, 2004, 2005, 2006, and 2007.

(iii) a total dissolved gas standard for the Columbia River of a daily (12 highest hours) average of 115 percent as measured in the forebays of McNary, John Day, The Dalles, and Bonneville dams, and at the Camas/Washougal monitoring stations;

(iv) a cap on total dissolved gas for the Columbia River during the spill program of 120 percent measured in the tailraces of McNary, John Day, The Dalles, and Bonneville dams' monitoring stations based on the highest 12 highest hourly measurements per calendar day; and

(v) a cap on total dissolved gas for the Columbia River during the spill program of 125 percent, based on the highest two hours during the 12 highest hourly measurements per calendar day during these times;

(vi) a requirement that if 15 percent of the juvenile fish examined show signs of gas bubble disease in their non-paired fins where more than 25 percent of the surface area of the fin is occluded by gas bubbles, the Director will terminate the variance; and

(vii) a requirement that the Corps provide written notice to the Department within 24 hours of any violations of the conditions in the variance as it relates to voluntary spill. Such notice shall include actions proposed to reduce total dissolved gas levels or the reason(s) for no action;

(viii) no later than December 31 for each year of this variance, the Corps shall provide a written report to the Department detailing the following:

a) flow and runoff descriptions for the spill season;
b) spill quantities and durations;
c) quantities of water spilled for fish versus spill for other reasons for each project;
d) data from the physical and biological monitoring programs, including incidences of gas bubble discease;
e) progress on implementing the measures contained in the Lower Columbia River Total Dissolved Gas TMDL.

(ix) The Corps shall provide the Commission with an annual written report and, if requested, the Corps shall appear before the Commission to report on any of the above matters, or such other pertinent matters relating to total dissolved gas as the Commission may determine;

(x) The Commission reserves the right to terminate or modify this variance at any time during its currency.

Note: Completion and submittal of this document by 31 December 2004 satisfies requirement viii (a-d).

State of Washington:
WAC 173-201A-200(1)(f): Aquatic life total dissolved gas (TDG) criteria. TDG is measured in percent saturation. Table 1 lists the maximum TDG Criteria for each of the aquatic life use categories.

TABLE 1

Aquatic Life Total Dissolved Gas Criteria in Fresh Water

Category	Percent Saturation
Char	Total dissolved gas shall not exceed 110 percent of saturation at any point of sample collection.
Salmon and Trout Spawning, **Core** Rearing, and Migration	Same as above.
Salmon and Trout Spawning, **Noncore** Rearing, and Migration	Same as above.
Salmon and Trout Rearing and Migration **Only**	Same as above.
Non-anadromous Interior Redband Trout	Same as above.
Indiginous Warm Water Species	Same as above.

WAC 173-201A-200(1)(f)(i): The water quality criteria established in this chapter for TDG shall not apply when the stream flow exceeds the seven-day, ten-year frequency flood.

WAC 173-201A-200(1)(f)(ii): The TDG criteria may be adjusted to aid fish passage over hydroelectric dams when consistent with a department approved gas abatement plan. The elevated TDG levels are intended to allow increased fish passage without causing more harm to fish populations than caused by turbine fish passage. The following special fish passage exemptions for the Snake and Columbia rivers apply when spilling water at dams is necessary to aid fish passage:

- TDG must not exceed an average of one hundred fifteen percent as measured in the forebays of the next downstream dams and must not exceed an average of one hundred twenty percent as measured in the tailraces of each dam (these averages are measured as an average of the twelve highest consecutive hourly readings in any one day, relative to atmospheric pressure); and
- A maximum TDG one hour average of one hundred twenty-five percent must not be exceeded during spillage for fish passage.

Under the provision provided in WAC 173-201A-200(1)(f)(ii), in a letter dated February 27, 2004, the Washington Department of Ecology approved the gas abatement plan that they had on file for a period of one year and approved a special fish passage exemption so that dissolved gas levels may be raised above 110 percent saturation to aid fish passage. The Corps was also instructed to continue to evaluate, refine, implement, and report on gas abatement activities as needed.

<u>Colville Tribe TDG Standards:</u>
4-8-5(e): The Water Quality Standards herein established for the total dissolved gas shall not apply when the stream flow exceeds the seven (7) day, ten (10) year frequency flood.

4-8-6(b)(3)(E): Total Dissolved gas shall not exceed one hundred-ten (110%) percent of saturation at any point of sample collection.

1.1.5 Operating Guidelines

The Water Quality Team of the Corps 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 adjustments are made, the water volume, water elevation (where applicable), project powerhouse and spillway characteristics (where applicable), and short- and long-term weather forecasts were included in the evaluation.

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 general information about each FMS operated by the Corps and a map of their locations.

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 Regional Forum Technical Management Team to make recommendations on dam and reservoir operations.

A web site description of the TMT can be found at:

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

The 2004 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 for 2004 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

The 2004 Water Year, which began in October 2003, was average in precipitation. The accumulative precipitation during water year 2004 in the upper Columbia River Basin was 104 percent of normal (1971-2000) above Grand Coulee Dam, 101 percent of normal in the Snake River above Ice Harbor Dam, and 104 percent of normal in the Columbia River above The Dallas, Oregon (Western Region Climate Center). The following month-by-month discussion of the weather provides more detailed information.

Late in October 2003, a continental airmass entered the region, bringing colder than normal temperatures, and drier conditions in northern regions. This pattern held through November, producing many low temperature records, some of which occurred in several spots west of the Cascades. For October through November, precipitation was 92 percent of normal at Columbia above Grand Coulee, 60 percent of normal at the Snake River above Ice Harbor, and 83 percent of normal at Columbia above The Dalles. Although not a record, Spokane registered –9 ^{0}F (-22.8 ^{0}C) on 22 November 2003. For the lead fall months, regional temperatures departed +3.7 ^{0}F (+6.8 ^{0}C).

Most of December was wetter-than-normal as this maritime, westerly flow brought in frequent fronts. The core of the storm track ran across the U.S. part of the basin, rather than in Canada. As such, precipitation was 131 percent of normal at the Snake River above Ice Harbor, 98 percent of normal at Columbia above The Dalles, but 73 percent of normal at Columbia above Grand Coulee. While much of the month was mild, another cold, continental airmass moved south into the region later in the month. It combined with the antecedent moist flow to bring snow into the Willamette Valley, the north Oregon Coast, and through western Washington. Thus began a turn toward a very cold start to winter, even though the mild part of the month was sufficient to skew December's regional departures to +2.9^{0}F (+5.2 ^{0}C).

About mid-January 2004, the pattern shifted to warmer and wetter weather, with several daily precipitation records: 1.76 inches (45mm) at Olympia, 2.59 inches (65mm) at Astoria, and 1.63 inches (41mm) at Seattle. Overall precipitation was 106 percent of normal at Columbia above Grand Coulee, 104 percent of normal at the Snake River above Ice Harbor, and 101 percent of normal at Columbia above The Dalles. January's regional temperature departures were –0.1^{0}F (-0.2 ^{0}C), but were not indicative of the mean swing from –4.9 ^{0}F (-8.8 ^{0}C) to +5.3 ^{0}F (+9.5^{0}C), brought about by the weather pattern change.

During February 2004 the cold air of January settled in deeply over southern Idaho through to the Great Basin, and resulted in much below normal temperatures due to strong temperature inversions. High pressure, that caused these inversions, resulted in below normal precipitation for the southern and Canadian basins. Most of the rain and snow fell about mid month, due to a series of cold fronts in a westerly flow targeted over mainly the central regions, containing the Clearwater, Lower Granite, and Lower Snake districts. The fronts brought the monthly precipitation to only 54 percent of normal at the Columbia above Grand Coulee, 95 percent of normal at the Snake River above Ice Harbor, and 72 percent of normal at Columbia above The Dalles. Temperature departures were –1.0 ^{0}F (-1.8 ^{0}C), with mean departures ranging from –7.5 ^{0}F (-13.5^{0}C) to +4.5^{0}F (+8.1^{0}C).

From late February through early March, the higher sun angle easily broke the temperature inversions, and combined with the development of a high-pressure area in the upper air, resulted in warmer-than-normal temperatures for March. The upper level high was effective in detouring and/or weakening fronts as they moved inland. March precipitation was therefore below average, registering 83 percent of normal at Columbia above Grand Coulee, 40 percent of normal at the Snake River above Ice Harbor, and 94 percent of normal at Columbia above The Dalles. The monthly, regional temperature departure reflected the upper air pattern: +4.0 ^{0}F (+7.2 ^{0}C), with record high temperatures at several locations. Some daily readings were all-time March records, such as 78 ^{0}F (26^{0}C) at Missoula on the 30th.

In April a few strong fronts dented the upper high, and precipitation crept close to normal. April precipitation was 77 percent of normal at Columbia above Grand Coulee, 70 percent of normal at the Snake River above Ice Harbor, and 72 percent of normal at Columbia above The Dalles. The effective precipitation occurred mainly in mid-month, with drier conditions prevailing at it's start and close. Regional temperatures departed +2.9^{0}F (+5. ^{0}C), with another set of daily record readings, notably 75 ^{0}F (24 ^{0}C) on the 30th at Astoria.

In May, the weather was wetter and mild. At least two upper level low pressure troughs moved through the region, further caving in the once-established upper high. Warmer-than-normal offshore water temperatures likely helped keep nighttime minima above normal. This, coupled with the onshore flow brought about by these transient upper troughs, resulted in quite a bit of cloud cover and precipitation. May was a boost to streamflows, with its precipitation at 124 percent of normal at Columbia above Grand Coulee, 145 percent of normal at the Snake River above Ice Harbor, and 140 percent of normal at Columbia above The Dalles. A daily rainfall record was set at Spokane on the 21st, with 2.19 inches (56mm). The regional temperature departure was close to normal, at +0.3 ^{0}F (+0.5 ^{0}C), with some chilly readings in western Montana helping to skew the values.

In June, the upper air high that weakened from its March strength regained footing. Nonetheless, the strengthening of the ridge, and the locking-in of low pressure, once again, east of the Rockies signaled a turn toward warmer and drier weather, especially mid to late in the month. As such, June precipitation was 79 percent of normal at Columbia above Grand Coulee, 97 percent of normal at the Snake River above Ice Harbor, and 92 percent of normal at Columbia above The Dalles. A strong and wet thunderstorm pattern resulted in these higher values for the Snake River above Ice Harbor. For June, regional temperatures departed +1.5 ^{0}F (+2.7 ^{0}C).

Summer began warm, extending through its first full month of July, with only a temporary low-pressure trough bringing another round of strong and wet thunderstorms to the same regions as that in June. As a result, July precipitation was greatest, relative to normal, above Ice Harbor at the Snake River, with 96 percent of normal. At Columbia above Grand Coulee, it totaled 77 percent of normal, and 76 percent of normal at Columbia above The Dalles. Along with the frequent thunderstorms and severe weather, the biggest story of July was the warmth, resulting in record high temperatures. These included readings for the 23rd: 96 ^{0}F (36^{0}C) at Astoria and 103 ^{0}F (39 ^{0}C) at Portland. Overall, the Basin's temperatures departed +3.0 ^{0}F (+5.4 ^{0}C).

The pattern remained largely unchanged through much of August, until the onset of the first few Atlantic hurricanes, and an active west Pacific typhoon cycle set the stage for a wet turnaround later in August. A burst of precipitation occurred between the 20th and

28th, elevating totals to above normal, and causing rises in streamflows. In a normally very dry month in most sectors, the resultant breakdown was impressive: 195 percent of normal at Columbia above Grand Coulee, 192 percent of normal at Snake above Ice Harbor, and 204 percent of normal at Columbia above The Dalles. August had many record precipitation events, within a nine-day period. Some of these included 1.07 inches (27mm) at Missoula, and 0.51 inches (13 mm) at Yakima. August regional temperatures departed +2.1 ^{0}F (+3.8^{0}C).

In September, cooler conditions developed as a shift in the weather pattern led to the development of an upper level low-pressure trough close to the Pacific Northwest to open. Temperatures departed roughly –2.0 ^{0}F (-3.6 ^{0}C), and regional precipitation ran near to slightly above normal, especially after storms in the first five days of the month.

2.1.2 Streamflow

The April 1, 2004 forecast of January through July runoff for the Columbia River above The Dalles was 90.5 km^3 (73.4 Maf) and the actual observed runoff was 90.0 km^3 (73.4 Maf). The average January-July runoff for the 1971-2000 period was 132.35 km^3 (107.3 Maf).

Precipitation was below normal through most of the fall of the calendar 2003 year, winter and spring of 2004. Only October 2003 and April 2004 experienced more normal precipitation and increased streamflow. However this did not significantly influence the overall water supply. Streamflow at The Dalles remained below average through the water year where the seasonal average. The January through July volume at The Dalles was 102.3 km^3 (82.95 MAF), 77 percent of the 1971-2000 average. The unregulated flow at The Dalles in 2004 was 11,546 cubic meters per second (m^3/s) (407,368 cubic feet per second (cfs)) on 31 May 2004 and a regulated peak flow of 8,184 m^3/s (289,000 cfs) occurred on 29 May 2004.

The Columbia River was operated to meet chum needs below Bonneville Dam from 13 November 2003 through May 2004. U.S. reservoirs were operated to target the 10 April flood control elevation per the NMFS 2000 BiOp for juvenile fish needs, but low inflow from January through March allowed Dworshak to refill to this target. For 2004 Libby Dam released the volume of water requested by the U.S. Fish and wildlife Service to meet downstream Kootenai River white sturgeon needs. The U.S. storage projects targeted full by 30 June 2004 per the Biological Opinion, but Libby failed to refill because of the sturgeon releases in June. Projects were then drafted to the NMFS 2000 BiOp draft limits for 31 August. Libby released steady outflow through July and August per an executive agreement and drafted only 4.27 m (14 feet) from full. Dworshak Dam reached the draft limit in September.

Composite operating year unregulated streamflows in the basin above The Dalles were below normal, and about 1 percent below last year’s below average streamflows. May had the highest unregulated flow during the spring runoff, at 78 percent of average. The August 2003 through July 2004 runoff for The Dalles was 132.2 km^3 (107.15 Maf), 78 percent of the 1971-2000 average. The peak-unregulated discharge for the Columbia River at The Dalles was 11,536 m^3/s (407,368 cfs) on 31 May 2004. The 2003-04 average monthly-unregulated streamflows and their percentage of the 1971-2000 average monthly flows are shown in Table 2 for the Columbia River at Grand Coulee and The Dalles. These flows have been adjusted to exclude the effects of regulation provided by storage reservoirs.

TABLE 2

Columbia River Flow in 2003-2004

	At Grand Coulee (in cfs)		**At The Dalles (in cfs)**	
Time Period	**Natural Flow**	**% of Average**	**Natural Flow**	**% of Average**
August-03	72,190	69	91,919	67
September-03	42,086	68	61,785	66
October-03	65,543	146	95,764	116
November-03	41,347	84	78,081	83
December-03	31,606	73	71,131	72
January-04	30,222	72	72,255	70
February-04	31,278	68	86,729	74
March-04	50,456	81	129,961	83
April-04	138,754	113	231,734	97
May-04	208,227	78	339,101	78
June-04	232,256	75	324,356	71
July-04	142,066	74	180,417	70
August-04	97,626	90	124,596	88
September-04	85,488	137	119,680	128
Operating Year Average (Oct 03 – Sep 04)	96,239	91	154,484	86

2.1.3 Reservoir Operation

2.1.3.1 General

The 2003-2004 operating year began with Canadian storage at 88.7% full. Libby reservoir (Lake Koocanusa) was not full on 1 August 2003 as the dam was releasing water to meet the objectives for flow augmentation for listed salmon species in the U.S.
The September through November period is typically a time of base flow at the reservoirs, but a late October rain event caused Canadian reservoirs and Libby reservoir to fill slightly. The January water supply forecast at the Canadian basins was slightly below average and remained below average through the spring. Because of less than average water supply the Canadian storage projects operated in proportional draft through early

spring and did not refill at the end of the operating year. Canadian storage ended the year at 88.5% full, near where they started.

Two CRTOC operating agreements enhanced fishery operations at Arrow. Libby Dam operated to meet the needs of both U.S. Fish and Wildlife Service 2000 Biological Opinion, and the National Marine Fisheries Service (now called NOAA Fisheries) 2000 Biological Opinion. Libby operated in accordance with the Libby Operating Plan of the Libby Coordination Agreement.

The Federal system was operated to meet the needs of listed chum downstream of Bonneville Dam beginning 31 October 2003. The operation meant maintaining the tailwater elevation at Bonneville Dam at, or above, elevation 11.2 feet, so as to keep the areas downstream of Bonneville wetted while the chum moved into the area and spawned. This tailwater elevation was the minimum allowable to Bonneville through the emergence of the chum in May.

Operations consistent with for the National Marine Fisheries Service, (now referred to as "NOAA Fisheries") BiOp, and the US Fish and Wildlife Service BiOp were completed in 2003-2004. The operations included refilling reservoirs to the 10 April flood control elevation. If inflow was great enough, refill on, or about, 30 June; and drafting reservoirs to summer draft limits. Because March and April were below average, the spring flow objectives at Priest Rapids, Lower Granite, and McNary were not met. Spill was executed at Lower Granite 20 day (4/3 – 4/23); Little Goose 16 day (4/7 – 4/23); and Lower Monumental 21 day (4/23 – 5/14). Spring and summer spill was executed at the other projects. The Lower Snake River projects were operated at, or near, their minimum operating pools for the season, except for Lower Granite from May 28 to June 5.

2.1.3.2 Flood Control

While the 2004 water supply forecasts averaged below normal across the Columbia River Basin, the reservoir system, including the Columbia River Treaty projects were still required to draft for flood control in preparation for the spring freshet. Inflow forecasts and reservoir regulation modeling were done weekly throughout the winter and spring. Projects were operated according to the 2001 FCOP, updated May 2003. With above normal precipitation in May and warm temperatures in June, actual runoff volumes were higher than forecast at the Columbia River Treaty projects. The unregulated peak flow at The Dalles, Oregon was estimated at 11,536 m^3/s (407,370 cfs) on 31 May 2004 and a regulated peak flow of 8,184 m^3/s (289,000 cfs) occurred on 29 May 2004. The unregulated peak stage at Vancouver, Washington was calculated to be 4.33 m (14.2 feet) on 31 May 2004 and the highest-observed stage was 2.96 m (9.7 feet) on 31 January 2004. Flood stage at Vancouver, Washington, is 4.9 m (16 feet).

In the 2004 spill season, there was only one small peak runoff period characterized by 330 to 350 kcfs total river flow, which prompted spilling for flood control. The peaks occurred on May 29 through June 2. The BiOp spill graphs in Appendix F illustrate the effects the one peak runoff period had on voluntary and involuntary spill at the various projects. During the peak runoff period, only Ice Harbor and McNary had involuntary spill since the river flow exceeded generation capacity.

2.2 Water Releases

2.2.1 Spill

Spring Spill
The spring spill program in the Snake River started on April 3 for Lower Granite, April 7 for Little Goose, April 24 for Lower Monumental and April 14 for Ice Harbor. But because of the provision in Action 40, 9.6.1.3.2 of the Biological Opinion, the spring spill program ended early; April 23 for Lower Granite and Little Goose and May 14th for Lower Monumental. Action 40 in 9.6.1.3.2 of the Biological Opinion calls for voluntary spill for fish passage to be implemented at all three Snake River projects when seasonal average flows are projected to meet or exceed 85 kcfs. When the seasonal average flows drop below 85 kcfs, then spill on the three Snake River projects may not be implemented. The projected seasonal average flows for the 2004 spills season was 77 kcfs. This provision applied to the 2004 spill season.

Total river flow on the Snake was low (between 37and 137 kcfs) from mid-May to mid-June, when flow began to taper off. There was voluntary spill for juvenile fish passage at all the Snake River projects ranging from 16 days at Little Goose to 21 days at Lower Monumental. Spill at Ice Harbor continued through to August 31. Of the Columbia and Snake River projects, McNary Oregon side forebay had the most exceedances with a total of 23 for the 2004 spill season.

The web site: http://www.nwd-wc.usace.army.mil/TMT/ contained NMFS regional forum TMT documents that outlined the rationale for determining which Columbia River projects to spill at and in what order.

The spring spill program in the Lower Columbia River started April 14 for McNary, John Day, The Dalles and Bonneville dams. The spring spill program for these projects ended on June 20. The 2000 NMFS BiOp calls for spilling forty (40) percent of the project outflow at The Dalles, but at no time is the project to spill more than the 120% gas cap voluntarily.

Summer Spill
The Summer Spill Program was characterized by below average river flows, which resulted in spill formally discontinuing at McNary on June 25th. According to Action 43 in 9.6.1.3.2 of the 2000 Biological Opinion, in general, the switch from spring to summer operation at McNary occurs on or about June 20 when conditions are no longer spring like. Spring-like is defined as favorable flow and water temperature conditions; i.e., river flows are at or above the spring flow target (220 to 260 kcfs) at McNary Dam, and ambient water

temperatures are below 62°F (17°C). At the June 23, 2004 TMT meeting, it was agreed that spring like conditions no longer existed at McNary and transport of fish would begin. Although McNary spill formally discontinued spill, the project continued to intermittently spill between 0 and 53 kcfs for the next six days when the total project outflow exceeded hydraulic capacity. Spill also continued at Ice Harbor, John Day, The Dalles and Bonneville until August 31. There was no summer spill at Lower Granite, Little Goose and Lower Monumental.

Spring Creek Hatchery Spill

Spill occurred at the Bonneville dam during the first week of March to facilitate 3.7 million juvenile Tule fall Chinook salmon passage. Spring Creek National Hatchery is located in Underwood, Washington upstream from Bonneville dam. From March 2 to 6, 2004, there was 50 kcfs spill released from Bonneville dam resulting in 103 to 105% TDG levels. Prior to the release, the US Fish and Wildlife Service obtained a TDG variance from Oregon DEQ that allowed for the elevated TDG levels associated with spill released in support of the hatchery release.

2.2.1.1 Special Spill Operations

During 2004, there were four special spill operations that varied from the regular spill operations for fish passage as described in the NMFS' 2000 BiOp. These operations occurred to accommodate tests with spill levels that were either higher or lower than those specified in the BiOp. The Corps developed the following tests, coordinated them through the Anadromous Fish Evaluation Program Studies Review Work Group (AFEP-SRWG), and interacted with NOAA Fisheries to obtain their concurrence. These tests were:

1. Lower Granite dam behavioral guidance structure (BGS) test
2. Lower Monumental spill test
3. Ice Harbor fish spill test
4. Bonneville fish spill tests

Lower Granite Dam Behavioral Guidance Structure Test

The purpose of the behavioral guidance structure (BGS) test was to determine the effects on juvenile fish passage and survival of making the structure shallower and changing the anchor point on the dam. The test involved moving the BGS in front of the powerhouse while spilling at the removable spillway weir (RSW) plus 12 kcfs (about 19 kcfs). Test spill operations were supposed to occur from April 15 through June 1 but because of low river flows the spill was discontinued early, on April 23, and the test was cancelled. This test is re-scheduled for the spring of 2005.

Lower Monumental Spill Test

The purpose of the test was to determine the effects of different spill patterns on fish survival. The test involved spill patterns under two conditions: bulk spill to the BiOp levels or bulk spill to the gas cap. The test was scheduled to span from April 15 through June 30. Because of low river flows and spill discontinuing early, the test was delayed at the April 14 TMT meeting and then modified at the April 21 TMT meeting. The agreed upon conditions for the test were five days (April 26th – April 30th) of spill before the test;

a bulk spill pattern from April 30th through May 14th and no spill from May 14 through May 24th. The test resulted in spill ranging from 19 to 39 kcfs, which produced TDG levels fluctuating between 116 and 121% as shown on Figure C-15 of Appendix C.

Ice Harbor Spill Test
The purpose of the spill test was to determine the effect of different spill levels and patterns on juvenile fish passage and survival. Spill for the Ice Harbor test lasted from April 15 to July 18 and consisted of two separate regimes. One regime, occurring about 50 percent of days, consisted of spill of 45 kcfs for 24-hours per day. For the other 50% of days, spill was to the gas cap (about 92 kcfs) for 24 hours per day. This test produced TDG level fluctuations between 110 and 120% as shown on Figure C-17 of Appendix C. Spill levels varied from 0 to 94 kcfs with an average of 69 kcfs.

Bonneville Fish Passage Spill Tests
The purpose of Bonneville fish passage spill test was to determine the effect of different daytime spill levels on adult passage and fallback rates. Spill for the Bonneville fish passage spill test varied between BiOp conditions and 50 kcfs. BiOp spill was spilling 75 kcfs during the day and during the nighttime, spilling to the gas cap or the project outflow, which ever is greatest. Test conditions were spilling 50 kcfs for 24 hours. Spilling 75 kcfs spill for 12 hours resulted in 107 to 111% TDG. Spilling to the gas cap for 12 hours resulted in a 95 – 175 kcfs spill with TDG levels between 115 to 119 %. Spilling 50 kcfs for 24 hours resulted in 106 to 109% TDG. The test used a randomized block design.

Another spill test was conducted during the Spring Creek hatchery release in March. The purpose of the Spring Creek release spill was to safely pass salmon smolts released from Spring Creek hatchery through Bonneville Dam. This was accomplished by spilling 50 kcfs from March 2 at 2000 hours to March 6 at 2000 hours. Instead of spilling at the main dam, the Bonneville Second Powerhouse corner collector was operated to bypass fish from March 11 at 1500 hours through March 15 at 1500 hours.

2.2.1.2 Voluntary and Involuntary Spill
The Corps Reservoir Control Center staff developed BiOp spill graphics in 1998 for daily operational monitoring of BiOp spill and has used them since. The Corps calculates the amount of BiOp spill, which is a part of voluntary spill, and those calculations and graphs are included in this report as Appendix F. The BiOp spill can be compared to the TDG levels by using Appendix C, which contains graphs of spill, flow, and TDG for the Snake and lower Columbia River projects.

Since Action 40 in 9.6.1.3.2 of the Biological Opinion applied to the 2004 spill season, voluntary spill discontinued but there were times when involuntary spill occurred at the three Snake River projects. The BiOp spill graphs and tables in Appendix F show all the Lower Columbia and Lower Snake Rivers projects, except Bonneville had some level of spill above the BiOp spill levels from May 4 to June 22, 2004. Because of the below average runoff, the amount of spill above the BiOp levels were low, ranging from 0 kcfs at Bonneville to 40 kcfs at Lower Granite. The amount of involuntary spill at Lower Granite ranged from 0 to 40 kcfs, the largest amount of spill above the BiOp level, which is due to the BiOp's provision of 0 spill when the average seasonal flow is below 85 kcfs. The amount of involuntary spill at McNary ranged from 10 to 33 kcfs, the second highest amount, which may be due to limited hydraulic capacity.

Involuntary spill occurred on the Snake and Columbia River projects from May 27 through June 9. From May 29 to June 2 the freshet peaked, with only 1 out of a possible 18 FMSs exceeded the 115/120% gas cap daily. The 2004 spill season freshet peak is very weak in comparison with the 2003 spill season when 14 or the 18 FMSs exceeded the 115/120% gas cap daily. As table M-3 of Appendix M shows, there were 4 FMS on the Lower Columbia and Snake River projects with no exceedances during 2004 spill season, which is four times more stations that 2003 spill season when there was only one gage with no exceedances. Involuntary spill was equally pronounced on the Columbia and Snake River. From May 29 through June 6, the tailwater FMSs at Ice Harbor; and McNary exceeded the 12 hours average TDG 120% gas cap twice each because of spilling involuntary for flood control. Graphs of the Snake and Columbia River projects' 12 hours average TDG levels shown in Appendix G illustrate the impact of involuntary spill levels on TDG levels during the May 27 to June 9 period.

Chief Joseph

There were 681 hours of TDG exceedance of the 110% TDG standard at the Chief Joeseph forebay from June 25 through August 11, 2004. The exact cause of these exceedances is not known, although it's probable that the high TDG levels at the Chief Joseph forebay were coming from the next upstream project, Grand Coulee. A review of the Grand Coulee tailwater TDG data suggest this is true. The Grand Coulee tailwater had TDG levels between 110 and 114% from June 26 through August 18 for a total of 404 hours, with many more hours in the 107 to 109.9 % TDG range. With the low flows and warm climate, the water temperature may have rose enough to cause a slight rise in the TDG levels, resulting in more TDG exceedances. The high TDG levels in the Chief Joseph forebay were carried through into the Chief Joseph tailwater, resulting in 861 hours of TDG exceedances of the 110% TDG standard. Table M-2 "Exceedances During Non-Spill Season" of appendix M provides a summary with the dates and % TDG.

Snake River Projects

There was a maintenance outage at Lower Monumental that resulted in involuntary spill at Lower Granite, Lower Monumental, Little Goose, Ice Harbor and McNary from September 1 through September 6. To accommodate needs for the outage, at the August 27, 2003 TMT meeting it was decided to lift MOP restriction for Little Goose on August 31, for Lower Monumental on September 1, and for Ice Harbor on September 2. This resulted in the projects filling during the planned outage and having involuntary spill above the amount that would maintain TDG levels below the 110% standard. Table M-2 "Exceedances During Non-Spill Season" of appendix M provides the dates and % TDG at the projects with exceedances that resulted from this maintenance outage.

Libby

The Corps installed a new water quality gage at Libby tailwater on March 9, 2004 called Kootenai River At Libby Dam (LBQM). This gage replaces the previous Libbly tailwater gage called Kootenai River Below Libby Dam (LIBM). Graphs of data from this gage are included in this report and can be found in Figures C-1 of Appendix C; Figure E-1 and Table E-2 of Appendix E and Figure H-1 of Appendix H.

As Table M-3 of Appendix M shows, there were 14 hours of exceedance of the 110% TDG standard at Libby tailwater. The 14 tailwater exceedances are attributed to unit outages, when a unit ran on speed-no-load. As Figure C-1 of Appendix C shows, there is a drastic drop in outflow at the same time that there is a spike in TDG. These graphic features are what you would expect to see when a unit outage occurs.

Albeni Falls

The Corps installed two new water quality gages at Albeni Falls: one as a forebay fixed monitoring station called ALFI and one as a tailwater fixed monitoring station called Pend Oreille River At Newport (ALFW). Data from the two new gages arrived at the Corps CROHMS database on April 29, 2004 (ALFI) and on May 5, 2004 (ALFW). Graphs of data from these two gages are included in this report and can be found in Figures C-2 and C-3 of Appendix C; Figure E-1 and Table E-2 of Appendix E.

As Table M-3 of Appendix M shows, there were 18 hours of exceedance of the 110% TDG standard at Albeni Falls forebay and 25 hours of exccedances in Albeni Falls tailwater. The tailwater exceedances may be attributed to unit outages and lack of hydraulic capacity. The project spilled between 12.6 and 21 kcfs during the hours of exceedances. On August 31, all three units were down and the total river was spilled causing exceedances for 8 hours. The cause for exceedances at the Albeni Falls forebay is unknown. There was no spill from Cabinet Gorge dam and there is no TDG data from Cabinet Gorge to know if the high TDG levels are from the project upstream of it.

Dworshak Dam

During 2004, there were 328 hours of TDG exceedances of the 110% gas cap at Dworshak Dam. It may be helpful to consider the TDG exceedances from a general overall annual perspective. As Table 3 shows, the hours and percent of time of exceedances for 2004 at Dworshak were higher than the previous years and the amounts of precipitation for 2004 water year was also higher. In 2004 Snake River upstream of Ice Harbor Dam was 104 percent of normal (1971-2000); in 2003 it was 89 and in 2002 it was 82 percent of normal. Even though the amount of precipitation was normal for the 2004 water year, the early April forecast showed a below normal water year and following forecasts showed continuing declines in forecasted precipitation. But May was wetter than forecasted, with precipitation at 145 percent of normal at the Snake River above Ice Harbor, which resulted in a the Dworshak reservoir filling sooner than expected. By May 27, the reservoir almost reached its maximum pool elevation of 1600 ft. Spilling for flood control operations began on May 27 and continued through June 10 resulting in 326 hours of TDG exceedances of the 110% gas cap. As a result of the flood control operations, TDG levels were between 110.1 and 121% (see Table M-3 "Exceedances of 110% Standard in Idaho and Montana" in Appendix M). The Dworshak TDG hourly data graph in Appendix C shows releases and TDG levels.

TABLE 3
SUMMARY OF ANNUAL TDG EXCEEDANCES
At Dworshak Dam

Year	No. of Hours Exceedances	Range of Exceedances	Possible No. of Hours Exceedances	Hours Spill Occurred	% of Hours in Exceedance	% of Hours Consistent w/Standards
2004	328	110.1 to 121.5	3312	1402	23.4	76.6
2003	15	110.1 to 113.7	3312	1798	0.83	99.4
2002	262	110.6 to 119	3312	2684	8	92.0
2001	2	110.1	3312	0	0.06	99.9
2000	146	114.2 - 110.1	3312	1776	8.2	91.8
Before 2000	Not Calculated	Unknown	Unknown	Unknown	Unknown	Unknown

2.2.2 Dworshak Releases

From early July through mid September, water releases from Dworshak Dam were adjusted and used to cool the lower Snake River. Water releases from Dworshak Dam for this purpose began on June 30, 2004 when Dworshak forebay elevation was at 1599.8 ft and continued until September 20, when the forebay elevation of 1520 ft was reached. An outflow of approximately 1.7 kcfs/hr was continued thereafter. TMT requested that the project outflow be maintained at 45^o F from July 1 through July 26. Calculations of how long 45^o F water could be maintained were prepared and can be found in Appendix D. These calculations are similar to those used in 2003 except for using slightly modified assumptions. Based on these calculations, there was enough water in the Dworshak reservoir to maintain 45^o F temperature for the entire Dworshak spill season. The volume of water to be released would be depleted before the 45^o F water would be depleted.

TMT requested that the project outflow be maintained between 43 to 44^o F from July 26 through August 4th, which occurred. TMT then requested that the project outflow be maintained at 45 to 46^{o}F from August 4th through to September 20th, which occurred. On September 21, when outflow went to minimum (1.7 kcfs), the water temperature went to approximately 47^{0}F. The Dworshak hatchery had to select between water temperatures of 47^{0}F (one unit in undershot mode, which is when water is drawn from underneath the selector gate) or 55^{0}F(one unit in overshot mode, which is when water is drawn from above the selector gate). They choose undershot with 47^{0}F.

Appendix D contains graphs showing the influence of Dworshak outflow releases and water temperature measured at the Lower Granite tailwater FMS. The benefit of the cold-water releases can be clearly seen in the Lower Granite tailwater temperature monitoring.

A 7 kcfs water release from Dworshak Dam began on June 30th. A water temperature change of 45 ^{o}F began on July 1. The 7 kcfs outflow with 45 ^{o}F water and the resultant Lower Granite tailwater daily average water temperature are shown on Figure D-2 in Appendix D. On July 6, the water releases were increased to 9.5 kcfs and 45 ^{o}F water maintained. The water temperature at Lower Granite tailwater peaked on July 1 at 68.5 ^{o}F, the highest during the 2004 spill season. As the Dworshak releases excreted an influence, the Lower Granite tailwater water temperature dropped to 65.5 ^{o}F by July 12. Then the Lower Granite tailwater water temperature began to creep back up and by July 25 it peaked a 68.1 ^{o}F. The Dworshak releases were increased to 13.6 kcfs on July 23. Approximately four days later, the the Lower Granite tailwater water temperature began to decline again. This harmonizes with the travel time for the river mass to travel from Dworshak to Lower Granite. It takes approximately five days for the river mass to travel from Dworshak to Lower Granite when there is a total river flow of 50 kcfs on the Snake and 5 kcfs on the Clearwater. The river mass travel time is less if the total river flows are higher. The Lower Granite tailwater water temperature remained below 68 ^{o}F through the rest of the spill season. Figure D-2 of Appendix D provides a summary of this information in a graphic style.

In 2004, the Lower Granite tailwater hourly water temperature exceeded the 68^{o} F State standard for 10 hours on four days: four hours on July 1 with temperatures ranging from 68.1 ^{o} F to 68.5 ^{o} F; two hours of 68.04 ^{o} F on July 2; one hour of 68.02 ^{o} F on July 23; and three hours of 68.1 ^{o} F on July 25. As shown on Table E-2 of Appendix E, the Lower Granite tailwater daily average water temperature did not exceeded the 68^{o} F State standard during 2004. Figure D-3 provides a graphic view of the tailwater temperatures for the Lower Snake projects. Ice Harbor had the highest water temperatures. The Lower Granite tailwater temperatures for 2000 through 2004 are graphed together in Figure D-4 so that a comparison may be made. The 2004 Lower Granite temperatures appear to be among the coolest of the years although a sharp, clear difference cannot be seen.

2.2.3 Beta Testing The SYSTDG Model

During the 2004 spill season, the RCC Water Quality unit beta tested the SYSTDG model, which Mike Schneider of the Corps of Engineer's Engineering Research Development Center (ERDC) developed. SYSTDG is a decision support tool used to estimate total dissolved gas (TDG) pressures resulting from project operations on the Columbia, Snake, and Clearwater Rivers. The parameters that SYSTDG incorporates into its forecast are total river flow; spill; wind; water temperature; forebay and tailwater elevations; barometric and total gas pressures; and tributary data. The RCC Water Quality unit used SYSTDG to forecast the TDG levels at the Corps Columbia and Snake River projects for the purpose of setting spill caps for each of the projects. Various approaches were used to discern which way is the most effective way of using SYSTDG in real time operations. A user's manual for SYSTDG was written that outlines a step-by-step guide on how to use SYSTDG. Based on RCC Water Quality Unit's experiences during the 2004 spill season, possible future developments were identified. In general, SYSTDG worked very well and the RCC Water Quality Unit looks forward to using it during future spill seasons. The RCC Water Quality Unit believed that a statistical evaluation of how accurately SYSTDG predicted % TDG levels during the 2004 spill season would be useful to quantify the uncertainty of SYSTDG estimates, establish the model as a credible tool in managing spill and identify areas for future improvements. The following is a short summary of the statistical evaluation that Dr. Mike Schneider performed. The full statistical evaluation can be found in Appendix N.

Statistical Evaluation

A statistical evaluation of the predictive errors was performed for the entire 2004 spill season. This evaluation was done so by comparing SYSTDG-calculated total dissolved gas pressures to observed TDG pressures measured by the fixed monitoring stations (FMS) located in the forebays and tailwaters of Corps operated dams within the Columbia Basin. The dams of interest included Bonneville Dam, The Dalles Dam, John Day Dam, McNary Dam, Ice Harbor Dam, Lower Monumental Dam, Little Goose Dam, Lower Granite Dam and Dworshak Dam.

SYSTDG simulations were run one project and river reach at a time so that predictive errors could be calculated independently for each dam and river reach. Predictive errors were calculated by subtracting the observed TDG pressures from calculated forebay or tailwater fixed monitoring station TDG pressures on an hourly basis. The predictive errors were calculated only during active spillway operations at each project at the tailwater FMS. The TDG pressures transported to the forebay of the next downstream dam were used to determine the predictive error during the period from April 15-June 8 for the Snake River Projects and from April 15 –August 31 for the Lower Columbia River Projects. The final predictive errors results are shown on Tables 4 and Table 5.

TABLE 4

Statistical summary of the predictive errors of the observed and calculated total dissolved gas pressures at forebay fixed monitoring stations.

Parameters		Predictive Error at Forebay FMS* (mm Hg)								
		LGS	LMN	IHR	MCQW	MCQO	JDY	TDA	BON	CWMW
Average		-3.5	-3.8	-2.4	-2.0	-3.8	-1.3	-6.1	-5.2	1.5
Standard Deviation		9.1	6.6	6.8	10.3	15.4	9.4	8.8	5.7	7.9
Maximum		44.1	27.6	26.6	37.6	71.3	29.7	26.5	12.6	27.5
Minimum		-25.2	-32.8	-30.2	-31.8	-42.3	-25.4	-25.5	-20.3	-22.6
TDG Predictive Error for Percentile Occurrence (mm Hg)	5%	-15.4	-14.6	-13.0	-19.3	-27.4	-13.5	-17.2	-14.5	-9.9
	10%	-12.7	-10.8	-10.3	-15.0	-23.1	-11.9	-15.5	-12.9	-7.8
	25%	-9.0	-7.1	-6.5	-8.8	-14.3	-7.7	-12.6	-9.4	-3.8
	50%	-5.4	-3.8	-2.6	-2.2	-4.4	-2.6	-8.2	-5.2	0.7
	75%	0.4	-0.6	1.2	5.3	4.5	2.9	-0.1	-1.6	6.3
	90%	7.8	3.6	6.1	10.8	16.1	12.8	6.6	2.1	11.8
	95%	14.5	8.1	9.5	14.7	24.3	17.2	10.4	4.6	15.5

* Predictive error is the observed minus calculated TDG pressure where negative values reflect an overestimation and positive values reflect an underestimation.

TABLE 5

Statistical summary of the predictive errors of the observed and calculated total dissolved gas pressures at tailwater fixed monitoring stations.

Parameters		Predictive Error at Tailwater FMS* (mm Hg)										
		DWQI	LGNW	LGSW	LMNW	IDSW	MCPW	JHAW	TDDO	WRNO	CCIW	CCIW-2
Average		-1.3	-11.3	-2.4	-25.7	-4.5	-12.7	-8.7	-0.5	-0.6	0.9	-14.5
Standard Deviation		11.3	15.8	14.7	21.9	19.5	10.0	9.3	8.1	12.6	13.4	14.8
Maximum		83.0	50.2	29.1	69.9	52.6	39.3	18.1	39.0	55.7	56.6	44.3
Minimum		-89.3	-64.2	-38.2	-88.6	-98.9	-41.2	-82.8	-55.4	-61.6	-61.3	-88.1
TDG Predictive Error for Percentile Occurrence (mm Hg)	**5%**	-18.0	-37.9	-32.5	-52.7	-36.0	-25.7	-25.9	-14.1	-15.6	-27.1	-49.7
	10%	-15.8	-32.3	-29.5	-43.3	-26.4	-24.1	-19.4	-10.9	-13.3	-15.1	-32.1
	25%	-8.5	-20.2	-8.5	-38.2	-16.4	-20.0	-11.9	-5.8	-9.3	-2.8	-19.4
	50%	-1.7	-9.2	-0.5	-32.8	-4.6	-13.6	-7.5	0.2	-2.1	2.2	-10.5
	75%	7.7	-2.8	6.6	-15.9	5.8	-6.7	-3.9	5.3	7.9	7.2	-6.4
	90%	11.4	5.3	14.9	7.5	22.2	-1.1	0.7	9.0	16.1	11.4	-2.5
	95%	13.3	10.6	19.8	13.2	30.5	2.6	4.1	11.1	19.9	14.4	1.4

* Predictive error is the observed minus calculated TDG pressure where negative values reflect an overestimation and positive values reflect an underestimation.

<u>Highlights of Statistical Evaluation</u>
The following are some highlights from the statistical evaluation:

- In general, the forebay station comparisons generated smaller predictive errors (Table N-1) than the tailwater station comparisons (Table N-2).
- Bonneville Dam forebay simulations produced the least amount of predictive error out of all the forebay sites evaluated based on the standard deviation statistic, while McNary forebay simulations produced the largest amount of predictive error. In general, the average forebay TDG estimates were biased on the negative side (over estimation) of observed conditions. Over 50 percent of the TDG projections were within +/- 1 percent saturation of the observed conditions.
- The determination of the predictive errors at forebay stations often consisted of a sampling bias component that resulted from a thermally induced pressure response. The relocation of many of the forebay FMS should greatly eliminate this source of error in the future.
- The smallest predictive error was calculated at The Dalles Dam tailwater, while the largest predictive error was associated with the Lower Monumental Dam

tailwater as shown in Figure N-41. The smallest predictive error was calculated at The Dalles Dam tailwater, while the largest predictive error was associated with the Lower Monumental Dam tailwater as shown in Figure N-41.

Future Improvements Identified

- The surface exchange coefficients should be adjusted to reduce the predictive error bias as determined at forebay stations. In some cases, the application of wind magnitude and direction data from alternative stations should be examined to see if predictions could be improved.
- The description of TDG exchange at all projects within the study area should be updated to reflect the patterns associated with recent data associated with both research studies and routine monitoring activities. In some cases, the contribution from the entrainment of powerhouse flows will constitute a major portion of the TDG loading generated at a project.
- The sampling biases determined at tailwater fixed monitoring stations should be addressed through relocation of stations and the application of TDG indexing. The tailwater stations located in mixed river environments are infrequently constrained by the tailwater TDG criteria of 120 percent. Detailed TDG exchange studies have clearly established consistent patterns of average and peak TDG pressures in spillway releases that differ from shore based observations from the fixed monitoring stations. In these cases, the average and peak TDG conditions in spillway flows can be implied or indexed to observations from the FMS.
- One improvement in calculating the TDG pressures in the tailwater is the use of a mixing zone correction that will influence estimates at small percent river spill conditions. During small percent spill conditions, the mixing zone can encroach upon water sampled at the tailwater FMS and reflect some mixture of powerhouse and spillway releases. At higher percent spill conditions the TDG characteristics reflect TDG levels in spillway releases undiluted from powerhouse flow.

Part 3 Program Results

3.1. Water Quality Review

Total dissolved gas and water temperatures are the two areas of the water quality program that this documents provides a detailed reviews with graphs of the data. Appendices C; E; G and M provide graphs and tables of TDG data. Appendices E and H provide graphs and tables of temperature data. Appendices A and B provide a general overview of the monitoring system with information on the fixed monitoring stations and the monitoring plan of action. Appendix D is specialized on Dworshak spill operations. Appendix I provide a review of the QA/QC for the TDG and temperature monitoring gages at John

Day, The Dallas, Bonneville, Warrendale and Camas/Washougal site. The U. S. Geological Survey (USGS) wrote the report for the Corps Portland District. Walla Walla District wrote Appendix J, which provide a review of the QA/QC for the TDG and temperature monitoring gages at Lower Granite; Little Goose; Lower Monumental; Ice Harbor; McNary and Dworshak. Seattle District wrote Appendix K, which provide a review of the QA/QC for the TDG and temperature monitoring gages at Libby, Chief Joseph and Albeni Falls.

3.1.1 Total Dissolved Gas

Operation of the Federal Columbia River Power System (FCRPS) to meet multiple purposes often necessitates spill operations that can result in exceedances of state water quality standards for TDG. The Corps, in accordance with the NMFS Biological Opinion, voluntarily spills for fish passage. In addition, spill at Corps projects occurs when there are physical or mechanic circumstances that necessitate it. For instance, when powerhouse capacity is exceeded, the intertie lines need repair, or unit outages, water is released through the spillway resulting in increased TDG levels.

The NMFS 2000 BiOp and applicable voluntary spill for fish program was implemented consistent with the State water quality standards variances or rule modification. During the spill season, the TDG level in the project forebays and tailwaters was monitored. Monitoring of TDG levels at the projects during spill season can be divided into two general categories:

1. Those that have TDG state standards of 110% based on an hourly reading (Idaho and Montana) and
2. Those that have TDG state standards of 115 or 120% based on the average of the 12 highest values in 24 hours (Oregon and Washington)

The projects in the States of Idaho and Montana have TDG state standards of 110% and all projects when they are spilling outside of fish passage season. The following discussions of exceedances are divided into states and by projects so the reader can know which standard applies.

Exceedances in Idaho and Montana

During the 2003/2004 water year, Idaho state standards of 110% TDG were exceeded at Dworshak for a total of 328 hours: 326 hours from May 24 to June 10, 2004 when spill for flood control occurred, and two hours on October 22 2003 for maintenance activities. As Table M-3 in Appendix M shows, the percent TDG during these exceedances ranged from 110.1 to 121.5%. Idaho state standards were exceeded at Albeni Falls forebay for 18 hours and the tailwater for 25 hours, with TDG levels ranging from 110.1 to 112.3%. The Albeni Falls tailwater exceedances are attributed to unit outages and lack of hydraulic capacity. For more information, refer to Appendix K for the Seattle District TDG Report.

Montana state standards of 110% TDG were exceeded at Libby tailwater for 14 hour with TDG levels ranging from 110.3 to 111.4%. The Libby tailwater exceedances are attributed to unit outages.

2004 TDG Exceedances – Washington and Oregon:

Washington and Oregon state standards during the 2004 spill season were exceeded 71 days at the projects on the Lower Columbia and Snake rivers out of a possible 3,020 days (number of projects x days in spill season). Table 6 provides a summary of TDG exceedances during 1999-2004 spill seasons. The totals shown on Table 6 may not be consistent with the number contained in the Corps Districts' appendices I, J and K. This difference is attributed in part to rounding; however, the Corps is looking at approaches to reduce the inconsistencies. The 71 high 12-hour average of TDG exceedances during 2004 spill season includes both voluntary and involuntary TDG exceedances and greater detail is provided on Table M-4 in Appendix M. The forebay TDG exceedances varied from 115.1 to 121.3%. The tailwater TDG exceedances varied from 120.1 to 125.6%.

TABLE 6

1999 - 2004 Spill Seasons
Number of TDG Exceedances

	2004	2003	2002	2001	2000	1999
Water Quality Gages	**Quantity**	**Quantity**	**Quantity**	**Quantity**	**Quantity**	**Quantity**
Lower Granite Forebay	0	0	0	5	2	0
Lower Granite Tailwater	0	15	17	0	4	15
Little Goose Forebay	3	10	17	0	2	39
Little Goose Tailwater	0	6	6	0	9	6
Lower Monumental Forebay	1	19	49	0	28	44
Lower Monumental Tailwater	1	10	6	0	12	26
Ice Harbor Forebay	4	35	24	0	34	44
Ice Harbor Tailwater	2	4	6	0	4	12
McNary Forebay - Wa.	10	24	43	1	14	22
McNary Forebay - Or.	23	32	45	5	22	19
McNary Tailwater	7	12	31	0	17	50
John Day Forebay	0	10	11	0	1	8
John Day Tailwater	0	0	29	0	12	43
The Dalles Forebay	5	11	18	0	5	1
The Dalles Tailwater	0	4	11	0	5	5
Bonneville Forebay	1	17	30	0	14	19
Cascade Island	0	---	---	---	---	---
Warrendale	0	1	19	0	6	2
Camas/Washougal	14	33	65	2	58	51
Chief Joseph Forebay	0	0	53	0	3	4
Chief Joseph Tailwater	0	0	11	0	0	1
Total Number of Exceedences	**71**	**243**	**491**	**13**	**252**	**411**

As Table 6 shows, the McNary Oregon and Washington sides and Camas/Washougal forebay FMSs had the majority number of exceedances during 2004 and were the most difficult to maintain within the 115% TDG standard. The McNary Oregon side station recorded the most TDG exceedances of the FMS system monitoring stations with 23 exceedances. The Camas/Washougal simulated forebay site had 14 exceedances, the second most for the season. Camas/Washougal is typically a location with a higher number of exceedances than other FMS locations. The McNary forebay location on the Washington side had 10 exceedances, which were attributed to the effects of solar radiation on water temperature and TDG levels.

Washington state standards were exceeded at Chief Joseph forebay for 681 hours from June 25 through August 11, 2004 with TDG levels ranging from 110.1 to 113.6%. Montana state standards were exceeded at Chief Joseph tailwater for 871 hours from May 30 through August 31, 2004 with TDG levels of 110.1 to 119.9%. The Chief Joseph forebay and tailwater exceedances are attributed to high TDG levels coming from Grand Coulee. Refer to Appendix K for the Seattle District TDG Report discussion on Chief Joseph and Libby.

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.

Comparison of Annual Exceedances

Table 7 provides a summary comparison of the total number of voluntary and involuntary spill related TDG exceedances for 1999 through 2004. As shown on Table 7, the 1999 – 2004 six year average of TDG exceedances during a spill season is 247 exceedances. The 2004 spill season occurrence of 71 TDG exceedances is 29% of the six-year average. This "lower than average" TDG exceedance rate is attributed in part to a lower than average water year precipitation during the months preceding spill season. It was because of unusually high amounts of precipitation in August that the 2004 water year was in the "normal" range with precipitation at 104 percent of normal (1971-2000) above Grand Coulee Dam, 104 percent of normal in the Snake River above Ice Harbor Dam, and 101 percent of normal in the Columbia River above The Dallas, Oregon. The month of August has precipitation at 195 percent of normal (1971-2000) above Grand Coulee Dam, 192 percent of normal in the Snake River above Ice Harbor Dam, and 204 percent of normal in the Columbia River above The Dallas, Oregon.

TABLE 7
SUMMARY COMPARISON OF EXCEEDANCES WITH PREVIOUS YEARS

Year	Days in Spill Season	Number of Days Exceeded	Percent Exceeding TDG Standard (%)	Percent Consistent with TDG Standard (%)
2004	3020	71	2.4	97.6
2003	3020	243	8.0	92.0
2002	3020	490	16.2	83.8
2001	3020	13	0.4	99.6
2000	3020	252	8.3	91.7
1999	3020	411	13.6	86.4
Ave.	3020	247	8.17	91.8

Note: For each exceedance during 2004, a reason for that exceedance was identified if known.

Type of TDG Exceedances

The type of TDG exceedances for the forebay and tailwater of each Corps project was daily tracked during the 2004 spill season. After some refinement, the Corps Reservoir Control Center used the previous year's list of TDG exceedance type definitions and applied them to the 2004 spill season. The types of exceedances represent conditions that caused TDG exceedances and are shown on Table 8. Table 8 also provides a summary of the types of exceedances tracking results of 2003 and 2004 spill seasons. A more detailed list of when and where the exceedance types occurred is provided in Table M-5 in Appendix M. The exceedance types designation given to each TDG exceedance is based on the Corps subjective determination of causation.

During the 2004 spill season, TDG exceedances were attributed to three main causes: sharp rises in water temperature alone (25 exceedances); sharp rises in water temperature with high TDG levels coming from the Mid Columbia River (10 exceedances); and uncertainties when using best professional judgment to apply the spill guidance criteria (16 exceedances). Approximately half of 71 TDG exceedances were caused in part or entirely by sharp rises in water temperature. This is understandable since spill ended early; there were low river flows and hot climate prevailed. The results from the 2004 spill season exceedance tracking are considerably different than 2003, when there were high river flows and spill for a longer period. As Table 8 shows, during the 2003 spill season, TDG exceedances were the result of three main causes: uncertainties when using best professional judgment to apply the spill guidance criteria (106 exceedances); high runoff flows and flood control conditions (68 exceedances); and bulk spill patterns being used which generated more TDG than expected (33 exceedances). The different reasons for TDG exceedances during 2003 and 2004 spill seasons stresses how various factors like river flow and spill can influence the number and type of TDG exceedances.

Exceedance type # 6: "uncertainties when using best professional judgment to apply the spill guidance criteria" was the only major TDG exceedance type that both 2003 and 2004 spill seasons had in common. This suggests that in spite of variations in spill, river flow or climate, there are TDG exceedances that result from application of the best professional judgment in setting spill caps for projects. This is where using SYSTDG during the 2004 spill season may have the potential of making a beneficial difference. A drastic decline in type 6 TDG exceedances can be seen when the types of TDG exceedances for 2003 and 2004 are compared. In 2003 there were 106 type 6 TDG exceedances and in 2004 there were 16. How much of this decline can be attributed to using SYSTDG during the 2004 spill season is not known. The water year experienced and the spill policies used will also strongly influence the types and numbers of TDG exceedances as can be seen with type 1 TDG exceedances: high runoff flow and flood control efforts. During 2003 there were 68 type one TDG exceedances and in 2004 there were 4. Future spill seasons will provide more information to better judge SYSTDG's influence on type 6 TDG exceedances.

TABLE 8
2003-2004 Spill Season
Types and Number of TDG Exceedances

2004	2003	TYPE #	DEFINITION
4	68	1	Exceedance due to high runoff flows and flood control efforts.
0	0	2	Exceedance due to Intertie line outages.
0	0	3	Exceedance due to unit outages during repair or maintenance.
0	0	4	Exceedance due to BPA inability to handle load so water was spilled.
0	1	5	Exceedance due to a break down in communication. Teletype went out but no change occurred or Project operator interpreted teletype differently than what was intended.
16	106	6	Exceedance due to uncertainties when using best professional judgment to apply the spill guidance criteria (travel time; degassing; water temperature effects; spill patterns).
0	18	7	Exceedance due to high TDG levels coming from the Mid Columbia River Dam(see Pasco FMS readings).
3	0	8	Exceedance due to high TDG levels coming from the Snake River projects(see Ice Harbor Dam FMS readings).
0	0	9	Exceedance due to a load rejection. The powerhouse was not working and the river was spilled.
6	7	10	Exceedance due to lack of information: the FMS gage malfunctioning and we had no information at the time of making spill change decisions.
0	9	11	Exceedance due to mechanical problems (gate was stuck open, passing debris etc.).
25	20	12	Exceedance due to sharp rise in water temperature (a 3 to 5 degree F. change in a day).
7	33	13	Exceedance due to bulk spill pattern being used which generated more TDG than expected.
10	0	12/7	Exceedance due to combination of exceedance type 12 and 7.
71	**262**		**Totals**

3.1.2 Recurring High TDG Exceedances

There were three locations that were difficult to avoid TDG exceedances from voluntary and involuntary spill, leading to high recurring TDG exceedances in 2004. As the 2004 data in Table 6 shows, there were high recurring exceedances at McNary forebays, Oregon and Washington sides and Camas/Washougal forebay. These three FMS sites have two similarities: all three are forebay FMS and experience thermal cycling. There is a distinction that should be made: The thermal cycling that occurs at Camas/Washougal is representative of the entire river where the thermal cycling at McNary is just representative of the thermal layers. The McNary forebay, Oregon and Washington sides both suffer from surface water influences and can experience temperature spikes up to 10^{o}F in one day. Camas/Washougal forebay can also experience temperature spikes although not as large as McNary forebays. McNary is also unique because it resided downstream of two projects (Ice Harbor and Priest Rapids) that spill a high percent of the river.

A review of the 1999-2004 TDG exceedances summarized on Table 6 highlights that these three FMS sites and Lower Monumental forebay have a history of recurring TDG exceedances. Camas/Washougal had the most exceedances during 1999, 2000, and 2002 spill seasons; the second most exceedances during 2004, 2003 and 2001 spill seasons. By comparison, Camas/Washougal has the most TDG exceedances of all the FMS sites (A total of 223 exceedances over the last six years). McNary forebay – Oregon side has the second highest amount of TDG exceedances over the last six years with a total of 146. Ice Harbor forebay, and Lower Monumental forebay are very close to McNary forebay-Oregon side with 141 TDG exceedances over the last six years.

3.1.3 McNary Forebay – Oregon Side

Historically, McNary forebay, Oregon Site FMS site has had a high number of TDG exceedance and 2004 spill season continues in this trend. As shown on Table 6, the McNary forebay – Oregon side had 23 days of exceeding the 12 hour average for TDG, the most TDG exceedances for the FMS system during the 2004 spill season. The McNary forebay is at the confluence of the Snake and Columbia rivers and receives waters that have not been fully mixed. Consequently, the water coming from the mainstem Columbia on the Washington side of the river often contains different TDG levels and water temperatures from the water entering from the Snake River on the Oregon side. Solar radiation heated the warmer water coming from the Snake River further, resulting in wide water temperature swings and TDG levels that were difficult to manage. With the low river flows and warm climate, the TDG exceedances due to sharp rises in water temperature alone or sharp rises in water temperature with high TDG levels coming from the Mid Columbia River became prominent in 2004. This situation can be seen most clearly with the TDG exceedances at McNary forebay-Oregon side, which had ten TDG exceedances when there was no spill at the project. (See Appendix M, Table M-4).

3.1.4 Camas/Washougal

Historically, Camas/Washougal FMS site has had a high number of TDG exceedance and 2004 spill season continues in this trend. As shown on Table 6, the Camas/Washougal site had 14 days of exceeding the 12 hour average for TDG, the second most TDG exceedances for the FMS system during the 2004 spill season. The Camas FMS represents a theoretical forebay in the lowest reach of the Columbia River. Because the Camas FMS is located in an open river reach which more shallow, it responses more quickly to environmental influences. This site was significantly affected by environmental conditions such as changes in gorge winds, barometric pressures, changes in daily solar radiation, which resulted in swings in water temperatures. The aquatic plants' production of oxygen is also believed to be involved in causing diurnal variations in TDG. Consequentially, these factors contributed to the difficulty in making adjustment on how much to spill at Bonneville and still remain at or below the 115 percent TDG limit at Camas/Washougal. Half (7 out of 14) of the total number of exceedances at Camas/Washougal in 2004 was type #6 exceedances: "uncertainties when using best professional judgment to apply the spill guidance criteria". In 2003 the type #6 exceedances at Camas/Washougal were much higher: 82% (27 out of 33). This significant drop in type #6 exceedances at Camas/Washougal is likely attributed to using SYSTDG model to set gas caps and better understanding of total gas dynamics.

3.1.5 McNary Washington Side

As shown on Table 6, the McNary forebay, Washington side had 10 days of exceeding the 12 hour average for TDG, the third most TDG exceedances for the FMS system during the 2004 spill season. Historically, McNary forebay, Washington side has not been among the top three TDG exceedance FMS site locations, although it is not surprising that it is during the 2004 spill season. Since the thermal cycling that occurs at McNary is representative of the thermal layers, it is understandable that during low river flows and warm climate, the thermal layers could experience large temperature spikes resulting in TDG exceedances. Six of McNary forebay, Washington side's 10 TDG exceedances for the 2004 spill season were attributed to this impact

Because McNary is located downstream of two projects (Ice Harbor and Priest Rapids) that spill a high percent of the river, McNary forebay gages are impacted by the variation in flow regimes and the TDG levels they produced. This impact is accounted for in the TDG exceedances tracking where there are two TDG exceedance types just for TDG levels coming from Ice Harbor or Priest Rapids. Four of McNary forebay, Washington side's 10 TDG exceedances for the 2004 spill season were attributed to this impact (see Appendix M, Table M-5). This spill season, the McNary forebay, Washington side FMS experiences more impacts from upstream TDG levels than the McNary forebay, Oregon side FMS.

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. Consistency with state water quality standards for TDG in Idaho is based on the instantaneous TDG level not exceeding 110%.

Appendix G contains graphs of the high 12 hour average TDG values for each monitoring station for the 2003 spill season. The graphs also include representation of the applicable standard (110% for Idaho stations, and Oregon and Washington forebays at 115% or tailwaters at 120%).

As shown on Table 6, there were a combined total of 71 exceedances of the average of the high 12 values in 24 hour measured at the FMS on all Columbia and Snake river projects. There were seven gages with no TDG exceedances during the 2003 spill season: Lower Granite forebay and tailwater; John Day forebay and tailwater; Little Goose and The Dalles tailwater and Warrendale. As the 1999-2004 summary of TDG exceedances on Table 6 shows, no exceedances at Lower Granite forebay is somewhat typical.

3.3 Water Temperature

This report contains three appendices that summarize or use water temperature data: Appendix H shows hourly water temperatures in the forebays and the tailwaters of the Corps projects and Appendix E has Table E-2 which shows the number of days that 68^{0}F is exceeded on a daily average and for one hour or more at the Corps projects. Appendix D contains graphs of Dworshak and Lower Granite water temperatures with a summary of the Dworshak spill operations.

The NMFS 2000 BiOp calls 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 time period when ambient conditions would typically cause the temperature to rise above 68^{0}F. As discussed in 2.2.2 Dworshak Releases, the Corps achieved the objective of drafting Dworshak from 1600 ft elevation to 1520 ft for water temperature reductions and flow augmentation on the Snake River. As discussed in Appendix D, the cold-water releases produced the desired effect of reducing and maintaining cooler water temperatures on the Snake River.

The water temperature standards for the states of Idaho, Oregon, and Washington are shown below in Table 9.

TABLE 9
State Water Quality Standards
Chief Joseph Dam

Project	Washington Standard	Oregon Standard	Idaho Standard
Chief Joseph Dam, Columbia River, RM 545.1	"Temperature shall not exceed 18° C (64.4 F) due to human activities. When natural conditions exceed 18° C (64.4 F) no temperature increases will be allowed which will raise the receiving water temperature by greater than 0.3° C (0.5 F). Incremental temperature increases resulting from point source activities shall not, at any time, exceed t=28/T+7). Incremental increase resulting from nonpoint source activities shall not exceed 2.8° C (5.4 F)." WAC 173-210A-130(21) and WAC 173-201A-030(2)	None	None

TABLE 9
State Water Quality Standards
The Lower Snake Projects

Projects	Washington Standard	Oregon Standard	Idaho Standard
Lower Granite Dam, Snake River, RM 107.5 **AND** Little Goose Dam, Snake River, RM 70.3 **AND** Lower Monumental Dam, Snake River, RM 41.6 **AND** Ice Harbor Dam, Snake River, RM 9.7	"Temperature shall not exceed 20° C (68 F) due to human activities. When natural conditions exceed 20° C (68 F) no temperature increases will be allowed which will raise the receiving water temperature by greater than 0.3° C (0.5 F) nor shall such temperature increases, at any time exceed t=34/(T+9)." WAC 173-210A-130(98)(a)	None	Lower Snake – Asotin (Idaho/Oregon border) to Lower Granite Dam pool, Hydrologic Unit Code (HUC) 17060103, Rule Section 130.02. Aquatic Life: COLD (Cold Water Communities) "Water temperatures of twenty-two (22) degrees C or less with a maximum daily average of no greater than nineteen (19) degrees C."

TABLE 9
State Water Quality Standards
The Lower Columbia River Projects

Project	Washington Standard	Oregon Standard
McNary Dam. Columbia River, RM 292.0 **AND** John Day Dam, Columbia River, RM 215.6 **AND** Bonneville Dam, Columbia River, RM 146.1 **AND** The Dalles Dam, Columbia River, RM 191.5	"Temperature shall not exceed 20° C (68 F) due to human activities. When natural conditions exceed 20° C (68 F) no temperature increases will be allowed which will raise the receiving water temperature by greater than 0.3° C (0.5 F) nor shall such temperature increases, at any time exceed 0.3 C (0.5 F) due to a single source or 1.1° C (2.0 F) due to all such activities combined." WAC 173-210A-130(20)	From June 1 to September 30, "To accomplish the goals identified in OAR 340-041-0120(11), unless specifically allowed under a Department-approved surface water temperature management plan as required under OAR 340-41-026(3)(a)(D), no measurable (defined as 0.25° F) surface water temperature increase resulting from anthropogenic activities is allowed:…(ii)when surface water temperatures exceed 68° F (20.0° C)." (OAR 340-041-0205(2)(b)(A). From October 1 to May 31, , "To accomplish the goals identified in OAR 340-041-0120(11), unless specifically allowed under a Department-approved surface water temperature management plan as required under OAR 340-41-026(3)(a)(D), no measurable (defined as 0.25° F) surface water temperature increase resulting from anthropogenic activities is allowed:…(iii) In waters and periods of the year determined by the Department to support native salmonid spawning, egg incubation, and fry emergence from the egg and from the gravels in a basin which exceeds 55° F(12.8° C)…" (OAR 340-041-205(2)(b)(A).(v) In water determined by the Department to support or to be necessary to maintain the viability of the native Oregon bull trout, when surface water temperatures exceed 50.0°F (10.0°C);

Part 4 Fish Passage Summary

4.1 Biological Monitoring

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 NOAA Fisheries 2000 BiOp and the state TDG variances calls for biological monitoring for Gas Bubble Trauma Disease, which the Action Agencies performed in accordance with RPA action 131.

"Gas Bubble Trauma Monitoring and Data Reporting for 2004" by the Fish Passage Center is shown in Appendix L. Sampling of juvenile salmonids for gas bubble disease was conducted at Bonneville and McNary dams on the lower Columbia River, and at Rock Island Dam on the mid-Columbia River. The monitoring sites on the lower Snake River included Lower Monumental, Little Goose and Lower Granite dams. Sampling occurred two days per week at the lower Columbia River sites and once per week at the lower Snake River sites. Sampling of fish occurred between April 13th and April 27th at Lower Granite Dam, April 14th and April 28th at Little Goose Dam, and April 12th and April 26th at Lower Monumental Dam. Sampling of yearling chinook and steelhead occurred through the spring at the Columbia River sites. Once subyearling chinook predominated smolt collections the sampling of subyearling chinook occurred at Columbia River sites to the end of August.

A total of 10,253 juvenile salmonids were examined between April and August 2003. A total of 18 or 0.18 % showed some signs of gas bubble trauma in fins or eyes. Fin signs were found in 18 or 0.18% of the fish sampled at all sites. No fish were found with severe fin signs (rank 3 or higher) while, 4 fish had fin rank 2, with the remainder having rank 1 signs. The prevalence of GBT signs at Rock Island Dam was higher than any other Columbia River site during the 2004 monitoring season as is typically the case each season. Because the Rock Island data may obscure other interannual trends in the occurrence of GBT signs among sites, it will be treated separately in the remainder of this report.

At the lower Columbia and lower Snake dams operated by the Corps, a total of 8,016 juvenile fish were examined, with 3 or 0.04% exhibiting signs of gas bubble disease, compared to 0.5% in 2003, 0.7% in 2002, 0.1% in 2001, 0.2% in 2000, 1.4% in 1999, 1.6% in 1998, 4.3% in 1997, 4.2% in 1996 and 1.3% in 1995. No fish were found with severe fin gas bubble trauma.

The Biological Opinion Spill Program was managed using the data collected for total dissolved gas levels. However, signs of GBT in fins of juvenile fish, examined as part of the biological monitoring, were used to compliment the physical monitoring program. The

NMFS set the action criteria for the biological monitoring program at 15% prevalence of fish having fin signs or 5% with severe signs (rank 3 or greater) in fins. The NMFS action criteria were never exceeded. This is similar to 2003, 2002, 2001, 2000, 1999, 1998 or 1995 when no exceedances occurred. But contrasts with 23 dates when GBT levels surpassed the action criteria in 1997, 20 in 1996.