ROCKY REACH WATER QUALITY MANAGEMENT PLAN

Final Draft

ROCKY REACH HYDROELECTRIC PROJECT
FERC Project No. 2145

~~July 28~~August 30, 2005

Public Utility District No. 1 of Chelan County
Wenatchee, Washington

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I. Introduction

Section 401 of the Clean Water Act requires that applicants for a hydroelectric project license from the Federal Energy Regulatory Commission (FERC) also apply for Section 401 Certification to comply with water quality standards and other appropriate requirements of state law. The Washington State Department of Ecology (WDOE) is responsible for issuing or denying the Section 401 certification for the Rocky Reach Hydroelectric Project (Project), or waiving such certification if it is not issued within a reasonable period of time, not to exceed one year.

WDOE is a participant in the Settlement Group negotiating conditions for relicensing of the Project, and has requested that Public Utility District No. 1 of Chelan County (Chelan PUD) provide the scientific and biological basis for WDOE's Section 401 certification. The Settlement Group has developed a Comprehensive Plan that provides the rationale and details behind proposed license articles that the Settlement Group will recommend for inclusion in the new license to be issued by FERC. The Rocky Reach Water Quality Management Plan is in response to WDOE's request and is contained in this chapter of the Comprehensive Plan.

Section II of this Executive Summary explains what it means to comply with the water quality standards and other appropriate requirements of state law. Section III describes the relationship of the Rocky Reach Water Quality Management Plan to the other chapters of the Comprehensive Plan. Section IV describes the existing agreements that support existing beneficial fish uses. Section V addresses the issue of compliance with the numeric criteria for total dissolved gas saturation (TDG) and temperature, the only two water quality parameters that sometimes exceed numeric water quality criteria in the Mid-Columbia Rivers. Finally, Section VI describes the adaptive management plan that will be implemented pursuant to the Section 401 certification.

Chelan PUD's pending license application to FERC will be the second license for operation of the Project, but it will be the first time a Section 401 certification is required because the Project received its first license in 1956, before the Clean Water Act was enacted. However, Chelan PUD has voluntarily been operating the Project in compliance with several permits and plans related to specific WDOE water quality concerns, such as Spill Prevention Control and Countermeasure (SPCC) Plans, National Pollution Discharge Elimination System (NPDES) permits, and TDG abatement plans. This Rocky Reach Water Quality Management Plan assumes that those existing plans and permit conditions will be incorporated into WDOE's Section 401 certification.

II. Reasonable Assurance of Compliance with Water Quality Standards and Other Appropriate Requirements of State Law

Before turning to the Project's ability to comply with the numeric criteria for temperature and TDG, it is important to recognize that these are only two aspects of the applicable water quality standards. Because the water quality standards must be complied with as a whole, this section describes the other water quality standards that cannot be violated while pursuing compliance with the numeric criteria for temperature and TDG.

First, the fundamental purpose of the water quality standards is to protect the uses of water designated by the state. "Each State must specify appropriate water uses to be achieved and protected." 40 C.F.R. § 131.10(a). Among those uses that must be protected are fish and wildlife, recreation, and industrial (including hydropower). 40 C.F.R. § 131.10(a).

The purpose of numeric criteria is to protect the designated uses. "States must adopt those water quality criteria that protect the designated use." 40 C.F.R. § 131.11(a). Thus, the numeric criteria exist to support the designated uses, not as ends in themselves, and not as something to be achieved regardless of the consequences for designated uses.

The Washington State Pollution Control Hearings Board (PCHB) recognized this in its recent decision upholding Ecology's Section 401 certification for the Lake Chelan Hydroelectric Project. In rejecting the notion that numeric criteria should be pursued even when the result would harm designated uses, the PCHB stated that "the primary aim of the § 401 certification … is to meet water quality standards *by complying with the intent and the substance of the standard rather than its numeric form*." PCHB No. 03-075, Final Order, at 15. (emphasis added).

Second, in addition to numeric criteria, state water quality standards contain narrative criteria and an anti-degradation policy that requires that designated and existing water uses be "maintained and protected." § 131.12(a), WAC 173-201A-070(1), 40 CFR §§ 131.6, .12(a); WAC 173-201A-030. For example, designated and existing fish and wildlife, recreational and industrial uses must, under the policy, be protected and maintained.

Third, any temperature and TDG measures included in the § 401 certification must be reasonable and feasible. RCW 90.48.010. Ecology's new water quality standards specifically provide that for "dams that cause or contribute to a violation of the water quality standards" the dam owner must identify "all reasonable and feasible improvements that could be used to meet standards…." WAC 173-201A-510(5)(b).

Fourth, the § 401 certification cannot require the Project to remedy water quality problems it did not cause. "With respect to Federal Energy Regulatory Commission licensed hydropower projects, the department may only require a person to mitigate or remedy a water quality violation or problem to the extent there is substantial evidence such person has caused such violation or problem." RCW 90.48.422(3).

Finally, the Section 401 certification must provide "reasonable assurance" of compliance with the applicable water quality standards. 40 C.F.R. § 121.2(a)(3). In other words, it is not necessary for WDOE to conclude that compliance is absolutely certain. Also, "reasonable assurance" of compliance does not mean that there can never be an exceedance of the water quality criteria. There are numerous examples in water quality permitting and enforcement where an occasional exceedance of a water quality parameter is not considered an impairment of the water quality of a water body. For example, in WDOE's Assessment of Water Quality for the Section 303(d) List (Water Quality Policy 1-11), the determination of whether there is an impairment of water quality for many pollutants, including TDG, is based on the persistence of the pollutant at levels in excess of the water quality standard. The criterion for persistence is when an exceedance of the standard is indicated for 10% of the water in the segment. The test is whether, with a given degree of confidence, the set of randomly collected samples accurately show that the water that the samples were taken from has a true exceedance percentage of at least 10%.

This requirement can be considered to apply to either a series of samples over space or over time. For example, 10 out of 100 hourly TDG readings would have to exceed the criteria before the waterbody segment could be listed as impaired for TDG. Further definition of what is a de minimis frequency of exceedances is found in the policy for consideration of short-term impacts. Water Quality Policy 1-11 states: "For impairments related to transient and recurring short-term conditions, such as storm events or small spills, a waterbody segment will not be considered impaired if those conditions occur on fewer than 30 days in a year."

Within this broader context, mechanical application of numeric temperature and TDG criteria is not an option. For example, if drawing down the reservoir behind the Project caused the Project to comply with the numeric temperature criteria, such a drawdown would nevertheless not be allowed because to do so would interfere with other existing beneficial uses, specifically recreation and hydropower generation. Similarly, if steps to meet the numeric TDG standard had the affect of harming designated fish uses more than would occur from the TDG at issue, such steps would, at least arguably, not be allowed.

These examples illustrate the need to assure overall compliance with the intent and substance of the water quality standards, rather than seeking to achieve mechanical compliance with the numeric criteria, regardless of the consequences for beneficial uses. Instead, a water quality management plan must appropriately balance compliance with the various provisions of the water quality standards, with the top priority being the protection of designated uses. This flexible approach is within the exercise of WDOE's discretion, and is necessary to fulfill the purpose and intent of the Clean Water Act.

In the Lake Chelan case, the PCHB decided that an adaptive management plan containing specific enforceable biological objectives in support of designated uses can provide reasonable assurance of compliance with the Clean Water Act, state water quality standards, water quality criteria, and antidegradation requirements. In doing so, it rejected the contention that the Clean Water Act requires strict adherence with the numeric water quality criteria as "an incorrect reading of the requirements of § 401 of the Clean Water Act." *Id.*, at 25. The PCHB found further support for its approach in the Aquatic Resources Mitigation Act, which authorizes Ecology to issue a § 401 certification for a hydroelectric project that "provides equal or better biological functions and values, compared to existing conditions." RCW 90.74.020(3).

Within this context, this chapter has been developed to provide for reasonable and feasible monitoring, evaluation, and control of TDG and temperature associated with the operation of the Project. The goal is to require "reasonable and feasible" measures to protect and enhance the designated uses of the River in a manner that provides "better biological functions and values, compared to existing conditions."

It is also important to note that WDOE's water quality standards are in the process of revision. Effective August 1, 2003, WDOE revised its water quality standards (Surface Water Quality Standards, Chapter 173-201A WAC, July 2003). Revised water quality standards, however, are not effective for federal Clean Water Act programs until they have been approved by Environmental Protection Agency (EPA); during the interim period, the previous water quality standards remain applicable.

On January 12 and February 14, 2005, EPA approved some of the 2003 water quality standards, but did not take action on others because of a need for more evaluation, as well as tribal consultation, Endangered Species Act (ESA) consultation, and essential fish habitat consultation under the Magnuson-Stevens Act. It is unclear whether EPA will complete this additional evaluation and consultation before the Section 401 certification is issued for the Project. However, EPA did conclude that the Compliance Schedule for Dams section in the 2003 water quality standards is an enforcement discretion provision under state law applicable to dam operations, which may be used by the State of Washington for purposes of its Section 401 certification. The Compliance Schedule for Dams states that: "For dams that cause or contribute to a violation of the water quality standards, the dam owner must develop a water quality attainment plan that provides a detailed strategy for achieving compliance." The plan must include a compliance schedule that does not exceed ten years. This chapter has been structured, with the measures described in Section 4, to provide be consistent with this regulation.

III. Relationship of the Water Quality Management Plan to the Other Chapters of the Comprehensive Plan

The Rocky Reach Water Quality Management Plan is intended to work in coordination with the measures undertaken pursuant to other chapters of the Rocky Reach Comprehensive Plan, each of which support beneficial uses recognized under the Clean Water Act. For example, Chapter 4, the Comprehensive Bull Trout Management Plan, is aimed at identifying and minimizing any negative Project-related impacts on bull trout passage (both adult and sub-adult) through the term of the New License. If a monitoring program identifies impacts, Chelan PUD will collaborate with the Rocky Reach Fishery Forum to identify reasonable and feasible options to modify upstream and downstream passage facilities or operations that reduce the identified impacts.

Similarly, Chapter 5, the Comprehensive Pacific Lamprey Management Plan, Chapter 3, the Comprehensive White Sturgeon Management Plan, and Chapter 6, the Comprehensive Resident Fish Management Plan would support the designated use of the Columbia River for these species.

Chapter 9, the Comprehensive Recreation Resources Management Plan, builds upon the foundation of Chelan PUD's seven existing parks to meet the growing need for recreation in the area. For example, Chelan PUD will design and implement upgrades to Entiat Park, which provides access to water-recreation. It will also make funds available for upgrades to the Entiat wastewater treatment plant; to the serve the needs of Entiat Park, make available funding for the development of recreation facilities; and, design and construct a trail linking the Park to an outdoor learning center.

IV. Existing Agreements Supporting Beneficial Fish Uses

This Rocky Reach Water Quality Management Plan and the accompanying Section 401 certification must work in concert with three existing agreements that already support beneficial and designated fish uses in the Columbia River. First, Chelan PUD is a party to the historic Anadromous Fish Agreement and Habitat Conservation Plan (HCP) for the Rocky Reach Project, along with the US Fish and Wildlife Service (USFWS), the National Marine Fisheries Service (NMFS, presently NOAA Fisheries), the Washington Department of Fish and Wildlife (WDFW), and the Confederated Tribes of the Colville Reservation (CCT). The object of the HCP is to achieve no net impact of the Project on anadromous species of salmon and steelhead. To that end, Chelan PUD in 2004 completed a $110 million juvenile fish bypass system to increase the survival of migrating salmon and steelhead.

Second, Chelan PUD is a party to the Mid-Columbia Hourly Coordination Agreement (Hourly Coordination Agreement), along with Douglas PUD, Grant PUD, and the Bonneville Power Administration (BPA). Under the terms of this agreement, the five non-federal dams on the Columbia River (Rock Island, Rocky Reach, Priest Rapids, Wanapum, and Wells) as well as the Grand Coulee and Chief Joseph federal projects are operated in a coordinated manner to optimize water use through this stretch of the Columbia River.

Because these seven projects are the primary source of electricity load regulation for the entire Pacific Northwest, the primary aim of the Hourly Coordination Agreement is to meet the region's peak energy needs while maintaining reservoir levels as stable and full as possible. From the perspective of fish health, the fact that the Rocky Reach reservoir and tailrace are more stable than they would be without the Hourly Coordination Agreement means that there is less need for involuntary spill, thereby reducing levels of TDG.

Third, the Hanford Reach Fall Chinook Protection Program Agreement (Hanford Reach Agreement) commits the Project to support Grant PUD's efforts to stabilize water levels for the protection of fall Chinook salmon during spawning, incubation, and early rearing. These agreements are described in more detail in Section 2.2, Project Flow Regulation and Generation.

V. The Project Compliance History

The Project complies with most narrative standards and numeric criteria, including those established for dissolved oxygen (DO), pH, turbidity, fecal coliform, nutrients/trophic level toxic or deleterious materials, and aesthetics. This conclusion is documented in Section 2.3 – Water Quality Baseline, and Section 2.6 - Oil and Grease Containment and SPCC Plan.

However, at times, the Columbia River within the Project boundary does not meet the numeric criteria for two parameters, TDG and water temperature; therefore, they are the main focus of the Rocky Reach Water Quality Management Plan. The Rocky Reach Water Quality Management Plan discusses the Project's effects on these parameters, potential actions to mitigate those Project effects, and an adaptive-management plan to manage those Project effects over time.

A. Total Dissolved Gas (Section 2.4)

As discussed in more detail below, the Project has a relatively minor effect on TDG levels, and those effects are already being alleviated by reducing spill. Based on a recent analysis of the

TDG characteristics and operational measures that have or could be implemented, the Project is likely to comply with TDG numeric criteria. Beyond reducing spill through additional operational changes, there may be some potential to further reduce TDG through structural modifications, but those steps could adversely affect the survival of salmon and steelhead passing through the spillway. The estimated cost of potential structural modifications ranges from $21 million to greater than $63 million. The Project's current design is already equivalent in TDG abatement to the TDG response observed at other Columbia River hydroelectric projects after they were structurally modified, and additional operational measures have been identified that are anticipated to make it possible to meet standards or special conditions criteria at all times. Moreover, there is no evidence that the current TDG levels are causing significant impacts on fish and other aquatic biota.

i. The Numeric TDG Standard

The numeric criteria for TDG is that it shall not exceed 110%, although that level may be exceeded when water is being spilled to aid fish passage, pursuant to a WDOE-approved gas abatement plan. Under such a plan, the average TDG level (highest 12 hours in a day) may not exceed 120% in the tailrace of each dam, and may not exceed 115% as measured in the forebay of the next downstream dam. The TDG limits do not apply when the stream flow exceeds the seven-day, ten-year frequency flood (7Q10).

ii. The Project Effect on TDG

The Columbia River did not always meet the numeric criteria for TDG before the Project existed, and would not always meet them even if the Project was removed. This is due to the modifications to the river caused by the construction of upstream hydroelectric and storage projects, which results in elevated TDG levels and water temperatures before the water enters the Project area.

The Project has an effect on TDG when spilling water, but the effect differs depending on the circumstances. Years of monitoring show that when TDG levels in water reaching the Project are near or below 110%, the Project's spill operations typically increase the TDG level at the downstream fixed monitoring site (DFMS) by 1-3%. When TDG levels arriving at the Project are between 115-120%, spill operations at the Project generally do not increase the average TDG levels at the downstream Rock Island Project. When TDG levels arriving at the Project exceed 120%, the Project's spill operations typically reduce TDG levels arriving at the Rock Island Dam. Regression analysis indicates that the Project can meet TDG numeric criteria at all flows up to the 7Q10 flow.

The Project has reported exceedances of the TDG criteria since 1997 (Table 1). Over that time period, exceedances were infrequent except during high flow events in 1997 and 2002, when flows frequently exceeded 200,000 cubic feet per second (cfs). However, only a small number of those exceedances were caused by the Rocky Reach Project. This record demonstrates that during high flow periods when upstream dams raise TDG levels above 120%, presenting the most potential risk to fish, the Project either has no effect on TDG or reduces TDG levels in the Columbia River downstream from the Project.

The record of TDG exceedances demonstrates that the level of spill used by the Project to increase juvenile fish passage survival has been successfully managed to meet water quality numeric criteria. From 1997 to 2004, there have been 140 exceedances of TDG in water arriving at the Project's forebay. Although Rocky Reach was also spilling when these exceedances occurred, the number of exceedances was lower at the Rocky Reach Project's DFMS (102) and at the Rock Island Project's forebay (137). An analysis of the exceedances below the Project during these years found that only 9 of the 102 exceedances of the 120% criterion at the DFMS and 17 of the 137 exceedances of the 115% Rock Island forebay criterion were caused by the Project's spill operations. The other exceedances were all caused by the high TDG levels arriving at the Project and would have occurred even if the Project had not been spilling. Since construction in 2003 of the juvenile bypass system, voluntary fish spill has not caused any exceedances below the Project. This trend is expected to continue due to the existence of the juvenile bypass system reducing the need for fish passage spill.

The levels of spill needed for fish passage in the future are not expected to increase and likely will be lower than used in these previous years due to the success of the juvenile bypass system, which was completed in 2003. Spill in 2003 was provided at the highest levels (15 - 25% of daily average river flow) during this first year of operation of the juvenile bypass system to assure that HCP fish survival objectives would be met. Based on the efficacy of the juvenile bypass system to meet fish survival objectives, less spill was needed in 2004, although the highest level of spill (24% of daily average) was still used for protection of sockeye salmon, with nighttime spill levels often exceeding 50% of the flow.

Nonetheless, exceedances were not observed at this time. As previously stated, there have not been any TDG exceedances downstream of Rocky Reach that were caused by the Project since 2002, prior to the juvenile bypass system. If the water arriving at the Project generally remains at or below a TDG level of 115%, the spill management procedures employed in conjunction with the juvenile bypass system appear to be able to maintain low TDG levels below the Project. Even during the 24% spill level in 2004, TDG levels at the DFMS, which is located approximately four miles down river from the Dam, only increased by an average of 2.4% above forebay levels (range 0% - 3.5%), and the hourly TDG level never exceeded 113.1%. The summer spill of 9% of the flow in 2004, which started on June 7 and ended on August 21, increased the TDG at the DFMS by an average TDG level of 0.7% (range -0.2% to 1.5%). The TDG level at the DFMS never exceeded 114.6%, although water arriving at the Project reached 114.3% TDG levels. This experience and expected future reduction in the need for voluntary spill by improving the efficacy of the juvenile bypass system demonstrates that the Project can comply with the TDG criteria in the future.

Recent work has indicated that under a standard spill pattern TDG levels in the tailrace, at the fish outlet for the juvenile bypass system, will not exceed 120% until spill discharges exceed 62,700 cfs (Schneider and Wilhelms, 2005; http://www.chelanpud.org/rr_relicense/study/reports/7773_1.pdf). This volume of water is approximately 25% of the 7Q10 flow of 252,000 cfs. As stated above, currently the highest level of spill is 24% of the daily average flow, with nighttime spill levels that may be higher. The daily average flow rarely reaches the 7Q10 flow level.

iii. Potential Measures to Reduce TDG

Chelan PUD has conducted a number of studies to determine if further abatement of TDG is feasible at the Project, and to determine the effect of current TDG levels on aquatic organisms when they are below the Project (Section 3.1 – Total Dissolved Gas). The most effective method to reduce the level of TDG caused by the Project is to reduce or eliminate spill, both involuntary spill and voluntary spill for fish passage.

As previously mentioned, the need for voluntary spill has been reduced with the completion of the juvenile bypass system and future actions are planned to continue this effort. Involuntary spill is minimized by the Project's participation in the Hourly Coordination Agreement, and by careful planning of turbine unit outages and other activities to avoid reducing hydraulic capacity of the powerhouse during time periods when inflows to the Project are highest.

Based on studies, Project personnel adjust spillway settings and operations to minimize increases in TDG levels. Project personnel monitor TDG levels and follow an established protocol to reduce spill, if possible, to avoid exceedance of criteria.

The potential to further reduce TDG during spill through additional changes to operations or structural modifications was investigated and the studies determined, for high spill levels, that use of more gates to reduce flow per gate could decrease TDG by a small amount, but would possibly affect passage of adult salmon seeking entrance into the adult fishways.

A detailed technical assessment of the TDG exchange characteristics of Rocky Reach Dam was conducted for current conditions and nine different operational and structural TDG management alternatives (Schneider and Wilhelms 2005). This analysis was based on direct observations of TDG exchange at Rocky Reach Dam and at other projects with a wide range of TDG management alternatives. In addition to a review of physical data, the theoretical basis for TDG gas transfer and best engineering judgment was employed to develop an assessment of the potential TDG management of various alternatives to Rocky Reach Dam.

The assessment concluded that of the nine alternatives explored, one operational and two structural alternatives would potentially decrease TDG in the river. The plausible operational alternative included investigating the impact of changing the spill pattern from the standard method of using bays 2 through 8 to a uniform spill from bays 2 through 12. This operation has the risk of adversely affecting the adult salmonids and steelhead passage, which would have to be studied carefully prior to implementation. The findings from a limited number of test conditions indicates a potential reduction in the average TDG levels of up to 2% using bays 2 through 12.

The two plausible structural alternatives identified were the construction of an entrainment wall that would keep the spill separated from the Powerhouse flows, and a pairing of alternatives consisting of raising the tailrace and constructing spillway flow deflectors.

The entrainment wall does not reduce dissolved gasses associated with spill but reduces mixing of powerhouse flow with spill, which can aerate powerhouse flow. This reduces the total mass of TDG produced by spill (Schneider and Wilhelms 2005). The initial investigation indicates the wall could reduce TDG level in the mixed flow by 0.8% to 1.0% under worst case conditions. It is important to note that when incoming forebay TDG levels are greater than 120% that the Project normally provides a net decrease in TDG levels, this alternative may increase the total TDG in the river.

The combination of a raised tailrace channel to promote the stripping of TDG and spillway flow deflectors to minimize the initial plunge of entrained air may result in an improvement in TDG management. Initial estimates indicate that TDG level may be reduced by 1.7 to 1.9%, and 4.0 to 4.2% in the mixed flow and tailrace under worst case conditions, respectively. However there remains considerable uncertainty in the estimates of TDG exchange associated with this alternative as applied to Rocky Reach Dam. The nappe deflectors would have to be removed to properly site the submerged spillway flow deflectors. This alteration would greatly reduce the energy dissipation properties of the stilling basin. It is likely that the tailrace channel would need to be armored to withstand the large hydraulic forces associated with spill delivered downstream of the stilling basin with spillway flow deflectors in place. Extensive hydraulic model studies will be required to develop a design that provides safe stilling action of spill, accommodates the guidance of adult and juvenile salmonids, and provides effective TDG management.

As previously stated, the estimated cost of potential feasible structural modifications ranged from $21 million to greater than $63 million and may adversely affect fish survival. The Project has a unique spillway stilling basin design that was found to have innate TDG abatement characteristics. The Project's current design is equivalent in TDG abatement to the TDG response observed at other Columbia River hydroelectric projects after they were structurally modified with TDG abatement measures, such as spillway deflectors and training walls. Spill management at the Project in 2003 and 2004 held TDG levels downstream of the Project much lower than allowed by the 120%/115% criteria. Additional investigative work to determine the impact of implementing spill in a uniform pattern from bays 2 through 12 is a likely next step to study TDG abatement during spills.

iv. Biological Effects of Current TDG Levels

Biological studies of the effects of current TDG levels on aquatic organisms, including studies of juvenile salmon and steelhead, resident fish species, and benthic macroinvertebrates, found very little evidence of any adverse effects on these organisms, even when TDG levels were higher than normal. Juvenile salmon and steelhead have been monitored for gas bubble trauma (GBT), which is caused by exposure to high TDG levels, at the Rock Island fish bypass trap.

Even though the Rock Island monitoring site in the fish bypass trap is known to induce GBT by holding fish in shallow troughs overnight prior to examination, the level of GBT symptoms observed in 2003 remained below 5% (GBT at other Columbia River sites in 2003 averaged less than 1%).

To put this level of GBT symptoms in perspective, the NOAA Fisheries' Federal Columbia River Power System (FCRPS) Biological Opinion requires that voluntary spill not be reduced until greater than 15% of fish sampled exhibit low-level GBT symptoms. The level of GBT in resident fish and benthic macroinvertebrates captured below the Project was studied in two years, 2001 when there was no spill and low TDG levels and 2002, when TDG levels were the highest observed in a decade (the high TDG came from hydroelectric projects upstream from Rocky Reach Dam). The levels of GBT symptoms observed in fish and macroinvertebrates below the Project were not different between 2001 (no TDG exceedances) and 2002 in the spring (TDG levels ranged from 103% to 127%). None of the resident fish collected in 2001 (3,777 fish examined) and during spring 2002 (2,134 fish examined) exhibited signs of GBT, despite the fact that they were collected from shallow water where exposure to TDG is most likely to result in GBT.

Similarly, benthic macroinvertebrates did not show signs of GBT, with only two of 7,405 organisms examined having GBT in 2001 and two of 9,885 organisms examined having GBT in 2002. Even an attempt to induce GBT in macroinvertebrates in 2002 by suspending organisms at a depth of one meter for seven days failed to produce any evidence of GBT in the 404 organisms examined.

Only during the first part of the 2002 summer sampling season, when TDG levels arriving at the Project exceeded 130%, were GBT symptoms observed in resident fish sampled below the Project. GBT was observed in 160 of the 866 fish examined from July to August. However, even with the extreme exposure to TDG levels exceeding 130%, most of the fish only exhibited minor GBT impacts.

From this evidence, it is clear that the Project, which successfully manages spill so that TDG levels do not exceed criteria (120% below the Project, 115% in Rock Island Dam forebay) does not cause adverse GBT effects to migrating salmon and steelhead, resident fish, or macroinvertebrates.

B. Water Temperature (Section 2.5)

i. The Numeric Temperature Standard

The 1997 Class A numeric temperature standard is that water temperature will not exceed 18°C due to human effects. When natural conditions exceed 18°C, no temperature increases due to human effects will be allowed which will raise the water temperature by more than 0.3°C. Additionally, incremental temperature increases from human effects in waters below 18°C will not exceed $t = 28 / (T + 7)$ where T is the background temperature, nor will they exceed 2.8°C.

ii. Project Effects on Temperature

Water temperatures in the Columbia River meet water quality standards most of the year, but frequently exceed temperature criteria of 18°C during the summer months. In the Project's reservoir, water temperatures typically exceed 18°C from late July to mid-September annually. These warm water temperatures are partly natural and partly the result of the development of the Columbia River hydroelectric and storage system upstream of the Project.

The main human effect on Columbia River water temperatures in the Project's area is the development and operation of storage reservoirs, such as the Grand Coulee Project. The EPA has conducted a water temperature model study of the Columbia River, using a 30-year period of weather and water temperature records. The EPA model found that the temperature regime in the upper Columbia River, including the Project's reservoir, is largely determined by the temperature of water released from Grand Coulee Dam, which retards warming of water temperatures in spring and early summer, then releases water warmer than pre-dam temperatures from late summer through the fall and winter.

Run-of-river hydroelectric projects, such as Rocky Reach Project, have a de minimis effect on water temperatures as the water moves downstream though the Project's reservoirs. The EPA determined that the Project's effect on water temperatures, on average over a 30-year period, was to slightly increase the tendency of water to warm up during the hot weather of summer and slightly increase the rate at which the water cools in fall and winter. The EPA's modeling effort could not precisely determine the Project's effect because the margin of error in EPA's model was greater than the measurable effect of the Project's reservoir and the model was set up to predict the averaged effects over a 30-year period. However, EPA's model did determine that the Project's effect on water temperatures under the present condition in the Columbia River is likely less than a 0.1°C increase in daily average water temperatures during hot weather in summer, and a beneficial cooling effect, beginning in mid-August, reaching a maximum of 0.2°C of cooling in late October, when Chinook salmon begin spawning in the mainstem Columbia River.

EPA also modeled the effect of the continued existence of the Project's reservoir on water temperatures at the downstream McNary Project. The cumulative effect of the Project was less than its local effect, with summer heating being less than a 0.05°C increase in average daily water temperature in summer and a 0.1°C cooling effect in fall and winter.

WDOE is presently deferring to EPA to model the temperatures of the Columbia River with no dams present in the United States. The EPA model analysis puts the Project's effects on water temperature into a suitable perspective for long-term management of the Columbia River. However, for 401 Certification the Washington State water quality standards are based on the daily maximum water temperature, rather than the daily average water temperature, and the time period is daily or weekly, rather than an average of effects over a 30-year period. Therefore, additional water temperature modeling was needed for WDOE to meet its mandate to determine if the Project meets the criteria for water temperature. Since the water temperature exceeds 18°C during the summer, the most relevant criterion in the water quality standards is the limitation of allowable increase due to the Project of 0.3°C above "natural" conditions. The true "natural" condition may never be known because both the incoming water temperatures and water flow levels reaching the Project are controlled by upstream federal projects.

For this reason, WDOE has chosen to use the existing water temperature and flow regimes entering the Project's boundary as the background temperature for the 401 Certification analyses to determine whether the Project's reservoir increases daily maximum water temperatures above the allowable incremental increase. In order to determine the Project's effect on daily maximum water temperature, a water temperature model study was conducted by an independent consultant, WEST Consulting, Incorporated, funded by Chelan PUD, in collaboration with WDOE, a peer review group of water temperature modeling experts, and a subcommittee of stakeholders in the relicensing settlement process, the Water Quality Technical Group.

The water temperature model used was a public-domain model, CE-QUAL-W2, Version 3.2, which is widely used to measure the effects of reservoirs on water temperatures and is being used to evaluate water temperature effects and mitigative actions in other parts of the Columbia River Basin.

The model was developed, calibrated, and subjected to a rigorous peer review. Once the model was found to be acceptable, emperical climatic data from 2000 and 2004 were input and water temperatures simulated for with and without Project conditions. For further assurance, the model output was compared to another prevalent model, MASS 1 for model years 2000 and 2001. The models were found to correlate within 0.2°C.

The total error of the comparison of with and without Project simulations is approximately 0.3 to 0.4°C. A comparison of the with and without Project flow-weighted daily maximum hourly temperatures was made at each of three locations (Beebe Bridge, Daroga Park, in the forebay) and subjected to the acceptability criteria described in the 1997 water quality standards.

At no time during the five years did the simulated impacts exceed the acceptable increase at Daroga Park or Beebe Bridge. On 19 days, the simulated impact at the forebay was greater than acceptable increases, however only one day exhibited a difference between the allowable increase and the simulated increase that exceeded the 0.4°C combined margin of error of the models.

The model was also used to compare the Project impact to proposed water quality standards, which consider a seven-day average of daily maximum temperatures and a criterion temperature of 17.5°C. On only one occasion was the simulated project impact greater than the acceptable incremental increase in years 2000 through 2004.

The long-term management goal for the Columbia River is to reduce high summer water temperature to the extent feasible. The EPA will be issuing a Total Daily Maximum Load (TMDL) for water temperatures on the Columbia River in the future, and it will be incumbent upon WDOE and other regulatory agencies to develop a detailed implementation plan for making reasonable and feasible improvements to reduce water temperatures for the benefit of salmon, steelhead and other sensitive beneficial uses.

This Rocky Reach Water Quality Management Plan investigated whether there were any reasonable and feasible actions that could be taken at the Project to reduce water temperatures during the summer months (Section 3.2, Temperature). A number of potential operational changes (increase daytime flows through release from active storage, operate at minimum pool), structural measures (selective withdrawal, solar barriers on fishways, cooling towers and chillers) and shade from shoreline vegetation were examined for feasibility in reducing water temperatures.

These potential measures were either infeasible or would not provide a measurable benefit. The operational measures would not have a measurable effect on water temperatures and would cause environmental damage by reducing reservoir habitat for fish and other aquatic organisms. The structural measures would either not have a measurable effect on temperature, or, in the case of cooling towers and chillers, were both massive in scale and would create a new, large consumptive use of water lost to evaporation.

For example, a cooling tower would not only be ineffective during much of the summer, to cool the river by 0.3°C would result in an estimated evaporation loss of 107 acre-feet of water per day, which is equivalent to a large municipal water supply. A chiller with the same temperature reduction capability would require 15 million feet of 2-inch pipe to transfer the same heat load (a 0.3°C temperature reduction) from the river to the coolant system. Then the coolant would still need an evaporation-based heat exchanger on land to cool the refrigerant.

Due to the width of the Project's reservoir, which has an average width of over 1,500 feet, even the tallest trees would have no measurable effect on water temperature from shade. The only action that was identified, which could improve water temperature conditions for migrating adult salmon and steelhead, was for the HCP tributary fund to include riparian vegetation and flood-plain reconnectivity projects that would reduce water temperatures in the tributaries. This would improve conditions for these sensitive species and reduce the heat load to the Columbia River.

IV. The Adaptive Management Plan

This Rocky Reach Water Quality Management Plan lays out an outcome-based adaptive management program for long-term protection of water quality and support for beneficial uses that rely upon water quality and water-based habitat or access (Section 4.0 – Protection, Mitigation and Enhancement Measures). As previously documented, the Project has no adverse effect on most water quality parameters and no actions are contemplated that would affect future compliance for these parameters.

The Project will continue to operate under agreements that support water quality and protection of beneficial uses, including the Hourly Coordination Agreement, the HCP, and Hanford Reach Agreements, as well as any successors to these agreements. The Project will also continue to operate in accordance with the SPCC Plan, revising and updating it as necessary to assure that water quality for toxic and deleterious substances is not adversely affected by operation of the Project.

The Project currently meets the TDG standard, and future actions are planned to assure that compliance continues throughout the term of the new license. The narrative requirements of the TDG standard require the Project to follow a gas abatement plan when providing voluntary spill for fish passage. In addition, WDOE has issued a TMDL for TDG in the mid-Columbia River and Lake Roosevelt, which incorporates current actions at the Project to meet the TDG criteria. The TMDL also sets load allocations for the times of year when voluntary spill is not used for fish passage. The Project rarely spills during this time of year, resulting in few occurrences of TDG levels that could exceed the 110% criterion. Spill for September to March rarely occurs for longer than a few hours or more than a few days in a month.

The adaptive management program for compliance with TDG water quality criteria and standards incorporates four actions. First, the use of voluntary spill for fish passage will be minimized by optimizing the efficacy of the juvenile bypass system and other measures, such as predator management, in meeting the HCP survival standards. Voluntary fish passage spill will continue to be managed to prevent exceedances, as was the case in 2004 when TDG levels never exceeded 113.1% at the downstream compliance location and 112.6% at the Rock Island Project's forebay, well below the allowable criteria of 120% and 115%, respectively.

Second, involuntary spill due to reduced hydraulic capacity will be minimized throughout the year by continuing to manage maintenance outages, scheduling work to avoid periods of high flows when reduced hydraulic capacity could result in involuntary spill to pass excess inflow. Involuntary spill past unloaded units will be minimized throughout the year by continual improvement in the management of flows and loads with the Hourly Coordination Agreement, regional load planning, and marketing arrangements during high flow years.

Involuntary spill has been effectively prevented by these methods, with only 11 hours of involuntary spill occurring in 2004. The fourth action in the outcome-based TDG adaptive management plan will be monitoring of GBT biological effects in salmon and steelhead, resident fish and macroinvertebrates to assure that the Project's TDG management is fully protecting the aquatic resources and preventing measurable harm from the Project's operation.

At the end of the compliance/adaptive management period, the Project's performance on TDG abatement and prevention of GBT effects on aquatic resources will be evaluated to determine if the resources have been adequately protected. If not, then Chelan PUD will determine, in consultation with WDOE, if additional reasonable and feasible actions are available for implementation in an additional adaptive management period. If Chelan PUD determines that reasonable and feasible actions to reach compliance are not available or otherwise provides adequate justification to modify existing standards, then Chelan PUD may submit such justification to WDOE and request that WDOE initiate a process to modify the applicable standards through rulemaking or other alternative process that may otherwise be authorized under applicable state and federal law.

The EPA TMDL for water temperature will establish load allocations and best management practices for operation of the hydroelectric projects on the Columbia River. Chelan PUD proposes to participate in water temperature monitoring, in conjunction with TDG monitoring, as its responsibility under TMDL implementation. Also, the CE-QUAL-W2 model developed for the Project will be made available to EPA and other entities involved in the TMDL implementation program.

Chelan PUD will participate and cooperate with the parties implementing the TMDL. In particular, it will participate in tributary watershed restoration planning and TMDL implementation planning to assure that the HCP tributary fund includes consideration of projects that improve water temperature in the tributaries.

In addition to these specific water quality actions, the Project will proceed with the adaptive management plans developed to support sensitive aquatic species that depend on the aquatic environment for their habitat. The outcome-based objectives developed in other chapters of the Comprehensive Plan for these species will further support and enhance these designated uses consistent with the goals and requirements of water quality standards.

SECTION 1: INTRODUCTION

Section 401 of the Clean Water Act requires that license applicants apply for state certification of compliance with water quality standards and other appropriate requirements of state law. The fundamental purpose of the Section 401 process is to protect the beneficial use of state waters. The Washington Department of Ecology (WDOE) is responsible for issuing or denying the Section 401 certification for the Project, or waiving such certification. The certification process considers the Project's compliance with the Clean Water Act, water quality standards, and other appropriate requirements of state law, including what measures can be employed to protect the beneficial use of the waters associated with the Project. These uses include fish and wildlife habitat, recreation, generation of electricity, water supply and irrigation. The WDOE, through the Section 401 certification, may require that certain specific actions or measures be included in the Project's license to support beneficial uses.

Chelan PUD applied for Section 401 certification in a letter dated June 29, 2004. -This request was submitted to FERC with the license application. Because the Comprehensive Settlement Agreement was not complete by June 20, 2005, Chelan PUD withdrew and reapplied on June 16, 2004. In the new application, Chelan PUD requested that the application not lead to another year of negotiations, but that rather 60-90 more days should be sufficient to complete the Settlement process. This Rocky Reach Water Quality Management Plan is the principal supporting document that has been submitted to be part of the 401 certification application. This Rocky Reach Water Quality Management Plan will become a chapter of the Comprehensive Plan that is being developed for the Settlement Agreement that will be submitted to FERC. The other chapters in the Comprehensive Plan provide additional information and proposed actions to support beneficial uses that also apply to the 401 certification.

In development of this Rocky Reach Water Quality Management Plan, Chelan PUD has conducted an extensive outreach to consult with federal and state management agencies, Native American tribes, municipal and county governments, environmental and recreation non-governmental organizations, and other interested parties. In this outreach, there have been numerous meetings conducted by Chelan PUD and WDOE, including relicensing water quality technical group meetings and public meetings. A complete record of these meetings can be accessed at the following Chelan PUD relicensing Web site, www.chelanpud.org/rr_relicense.

SECTION 2: BACKGROUND

2.1 Project Setting and Operations

The Rocky Reach Project, the eighth dam upstream from the mouth of the Columbia River, is a run-of-river hydroelectric project with limited ability to modify river flows. The Project has an allowable forebay fluctuation of four feet, with minimum forebay elevation of 703[1] and maximum of 707 feet for normal operation (710 under special flood control operation). However, in consideration of system reliability for the regional electric grid, the Project rarely allows the forebay elevation to drop below 704. The forebay elevation is usually maintained between 706-707. The forebay elevation has been above 706 over 73% of the time and within two feet of elevation 707 approximately 98% of the time, with average forebay elevation at 706.22 over a ten year period (1992-2001). The Project's tailrace elevation averaged 617.59 over the same time period. The maximum tailwater elevation during this period was 635.2 (June 12, 1997) and minimum was 610.7 (April 21, 1998). Tailwater elevation is determined primarily by Project discharge, which is managed under the Mid-Columbia Hourly Coordination Agreement, as described later in this section. On a daily basis, minimum and maximum discharge is related to the fluctuation in flows released from upstream federal dams, the Grand Coulee Project and Chief Joseph Project.

The Project's reservoir is 43 miles long, with an annual average flow of 113,200 cfs (1973-2001) since completion of Canadian storage reservoirs. The minimum daily average flow from 1973-2001 was 25,100 cfs (November 11, 1973) and the maximum daily average flow was 358,000 cfs (June 12, 1997). The surface area of the reservoir is approximately 8,235 acres at a flow of 100,000 cfs and forebay elevation of 707. The gross storage capacity of the reservoir at 100,000 cfs is 387,500 acre-feet. The volume of water that the reservoir can contain between the minimum and maximum forebay elevation is 36,400 acre-feet. This storage is useable for capturing or augmenting flow on an hourly basis. If inflow to the Rocky Reach Project ceased, the reservoir's useable storage would be sufficient only to run the plant for about two hours.

The inflow to the Project is primarily determined by operations of the Federal Columbia River Power System (FCRPS), which is composed of the federal dams and the accompanying electrical system on the Columbia and Snake Rivers in Oregon, Washington, and Idaho. The dams are operated by Reclamation and the U.S. Army Corps of Engineers, and generate hydropower that is marketed by the Bonneville Power Administration. The FCRPS is managed for a number of objectives, the primary being flood control, power production, protection of fish resources, recreation, and irrigation. In general, the FCRPS is operated to fill upstream storage reservoirs in June, then provide augmented flows for fish passage and power production through the summer. The FCRPS drafts storage reservoirs to meet power demand and salmon spawning requirements through the fall and winter. Depending on snow accumulations and runoff forecasts, during the spring the reservoirs may be further drafted for flood control and to meet flow targets for juvenile salmon migration periods. FCRPS operations from late May to July focus on managing reservoir levels to meet June refill targets and to be full at the end of July. The FCRPS manages

[1] All elevations of structures and water levels are in feet above mean sea level using national geodetic vertical datum (NGVD) 29 datum.

for these objectives using storage releases that pass through the Grand Coulee and Chief Joseph projects and adjusting for inflow from tributary streams above (the Okanogan, Methow and Entiat rivers) and below (Wenatchee and Snake rivers) the Rocky Reach Project. The FCRPS water management determines the daily, weekly and monthly average flows through the Rocky Reach Project.

Hourly flows at the Rocky Reach Project are also largely governed by hourly flow releases from Grand Coulee and Chief Joseph projects. However, the 36,400 acre-feet of useable storage at Rocky Reach, as well as useable storage at the Wells, Rock Island, Wanapum and Priest Rapids projects, is coordinated through operating agreements with the FCRPS to manage flow releases from Grand Coulee Dam for both power production and fish resource protection.

The primary operating agreement is the Hourly Coordination Agreement (1997 Agreement for the Hourly Coordination of Projects on the mid-Columbia River). The primary objective of the Hourly Coordination Agreement is to coordinate the hydraulic operation of the seven mid-Columbia hydroelectric projects (Priest Rapids, Wanapum, Rock Island, Rocky Reach, Wells, Chief Joseph, and Grand Coulee) in order to optimize the amount of energy generated from the available water consistent with the needs to both adjust the total actual generation to match the total generation requested to meet regional energy loads, and to operate within each hydroelectric project's power and non-power requirements. The effect of the Hourly Coordination Agreement is to optimize the operation of the seven projects for power production and other objectives, including fish protection. The framework of the Hourly Coordination Agreement is used to enable fish protection operations for fall Chinook salmon in the Hanford Reach of the Columbia River. A separate agreement, the Hanford Reach Fall Chinook Protection Program (formerly the Vernita Bar Agreement), sets flow management operations for the Priest Rapids Hydroelectric Project, including requirements for the other mid-Columbia projects, to provide flow and storage operations that support and enable the Priest Rapids Project to provide minimum flows and manage flow fluctuations as necessary to protect fall Chinook eggs and juveniles.

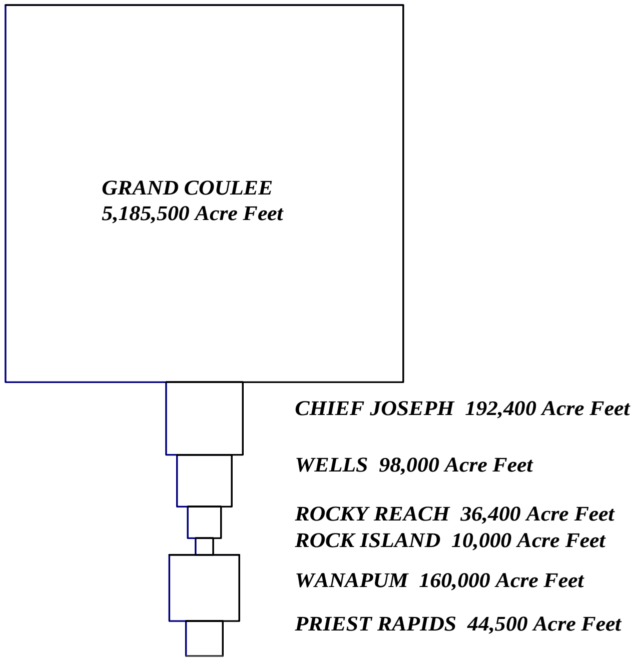


Figure 1: Mid-Columbia River Usable Storage

A more detailed discussion of how the Project is operated and the various agreements that influence the Project's operations follows in the next section of this Rocky Reach Water Quality Management Plan and in Appendix A. Additional background information on the Rocky Reach Project's relationship to the hydrology of the Columbia River, including additional discussion of the Project's flows, backwater effects, useable storage and flow management capabilities, is contained in Appendix B.

2.2 <u>Project Operations for Power and Fish Resource Protection</u>

2.2.1 Overview of Project Flow Regulation and Generation

The amount of flow that enters the Rocky Reach Project is regulated by releases from the federal Grand Coulee Project, which essentially dictates the flowage curve for all downstream projects on the Columbia River hydropower system. Seasonal demand for hydroelectric generation is governed by the Pacific Northwest Coordination Agreement (PNCA)[2]; however, non-power constraints such as flood control operations and the FCRPS Biological Opinion also dictate flow releases from the Grand Coulee Project. In the mid-Columbia, five non-federal hydroelectric projects (Wells, Rocky Reach, Rock Island, Wanapum and Priest Rapids projects) cooperate with each other and with the federal projects immediately upstream (Grand Coulee and Chief Joseph projects) through the Hourly Coordination Agreement to efficiently manage these releases to meet power demand and non-power operations for fish protection under the Hanford

[2] Grand Coulee Project releases are governed by the Pacific Northwest Coordination Agreement (PNCA). All generating utilities in the Northwest, with the exception of Idaho Power Company, are parties to the Agreement. The Agreement, in conjunction with the Canadian Treaty of 1964, provides a plan for optimizing water releases to meet power and non-power requirements on a seasonal basis.

Reach Agreement. The Hourly Coordination Agreement is set up to meet the daily demands of power load peaking while maintaining reservoir levels as stable and full as possible. These seven projects are the primary source for electricity load regulation for the entire Northwest.

Hydropower is a unique energy resource because of its ability to start and stop with relative ease compared to other energy sources, such as coal or natural gas, which require hours or days to bring additional capacity online to meet increased demand. If generation and load requirements do not match, the electrical system becomes unstable. Load regulation is the ability to adjust generation as often as every four seconds so that at every moment in time, the generation of the interconnected electrical system matches the load requirements being placed upon it by customer demand. The BPA uses the Grand Coulee and Chief Joseph projects as its primary tools to align supply with demand signals, while all major Northwest investor-owned and some public power utilities have shares of the generation output of the five mid-Columbia non-federal projects. These projects are used for load regulation because of their abilities to regulate river flows on a daily or hourly basis (Grand Coulee and Chief Joseph) or, in the case of the Rocky Reach Project, for a unique ability to adjust to changes in power demand on a real-time basis.

The Rocky Reach Project license provides for drafting the reservoir to the 703 elevation in anticipation of advancing floodwaters. However, Chelan PUD does not initiate this draft for flood control until signaled to do so by the US Army Corps of Engineers (COE). When the floodwaters do arrive, COE can ask for the reservoir elevation to be operated at 710 elevation. The COE would coordinate this drawdown and/or filling of the reservoir with all of its other flood control operations and obligations. This flood control operation has not occurred since 1972 and the COE has not ordered this operation since completion of Canadian storage in 1973.

Operation of the Rocky Reach Project is completely automated, including decisions to start, stop and adjust the output of the 11 generating units to achieve maximum efficiency. The automated functions are backed up with around-the-clock on-duty plant operators who monitor operations and can over-ride computer control if needed. When a generation request is transmitted from the central computer to the Rocky Reach Project's on-site computers, the most efficient way to meet the request is determined and implemented. Units 1 through 11 are adjustable blade Kaplan units and are efficient over a wide range of operating conditions. During the juvenile salmon migration, the plant operations are adjusted to assure that turbine units 1-2, which support the juvenile fish bypass system, are operating at all times and other units near the juvenile fish bypass system are operated in preference to turbines further from the bypass entrance.

Spillway releases to pass water in excess of turbine capability or load requirements, or for fish passage, are also controlled by computer. When the headwater level exceeds operator-set maximum points, gates are automatically opened to pass the excess flow. During fish passage operations, the sequence and amounts of gate opening can also be adjusted to maximize the effectiveness of the water being spilled for fish. During high water years, the Project operates at a higher plant factor and is more often subject to spill to pass flows in excess of plant turbine capacity. A higher plant factor implies that the Project is able to operate at or near full load for longer periods of time without drafting the storage from the reservoir. As flows increase, tailwater effects reduce plant capacity due to higher tailwater levels and lower available gross head. Under lower water supply conditions, the number of hours that the plant can sustain operations at or near peak load diminishes.

While the Rocky Reach Project has little control over river flow, operations do have some immediate impact on control of hourly fluctuations in reservoir level and discharge. The Rocky Reach Project is managed in accordance with the resource optimization framework set up through the Hourly Coordination Agreement. The history and purpose of the Hourly Coordination Agreement is described below.

2.2.1.1 Mid-Columbia Hourly Coordination Agreement

The hydroelectric projects on the mid-Columbia River were built between 1930 and 1967, with the first project (Rock Island Hydroelectric Project) being completed in 1932. Grand Coulee, the main storage facility on the river, was completed in 1942. The Rocky Reach Project did not commence operation until 1961, while the last project on the mid-Columbia, the Wells project, was completed in 1967. Until 1974, each of these projects operated independently, following demand signals by drafting and filling their reservoirs.

Prior to the Hourly Coordination Agreement, each project peaked (i.e. generated the daily maximum power which results in releasing the highest daily volume of water through the turbines) at different times to meet the requirements of its power purchasers. As the Wells Project peaked, water then moved down to the Rocky Reach Project which, by the time it arrived, did not need to peak, resulting in spill at the Project. The Wells Project, on the other hand was left drafted with insufficient inflow to refill until the next day or late evening. This uncoordinated operation resulted in a number of problems, ranging from inefficient power management to an inability to meet certain flow requirements for fish. Specifically, uncoordinated project operation led to:

1. Large headwater fluctuations at each project associated with each operator's independent attempts to meet load and purchaser demand at an individual project;

2. Large fluctuations in flow below Priest Rapids Project as a result of the uncoordinated drafting and filling of reservoirs being operated in an uncoordinated manner (typically, the reservoirs would draft during the weekend and then gradually fill early in the week as flows from the upstream federal reservoirs increased to meet Monday morning loads). The resulting lag left the lower Columbia short on water early in the week, potentially affecting spawning habitat, particularly in the Hanford Reach;

3. Loss of potential energy due to head loss, increased spill, and inefficient use of plant capabilities;

4. An inability to meet any fish protection flow requirements below Priest Rapids project;

5. Additional drafting of already low reservoirs to meet the 36,000 cfs minimum flow at Priest Rapids Project required by the Department of Energy for the Hanford Reach (related to cooling water for the Hanford Nuclear Reservation).

The mid-Columbia projects use the same water as it moves down the river and are intrinsically interdependent. Because they are affected by both upstream and downstream water management, operators soon realized that individual operation of the projects did not result in maximum efficiency for the system as a whole. This realization resulted in the first Hourly Coordination Agreement.

The Hourly Coordination Agreement was first signed in 1974 as a one-year agreement. It was then renewed in a series of longer-term agreements. The current agreement was signed in 1997 and extends until June 30, 2017. The Hourly Coordination Agreement is signed by the project owners (Chelan PUD, Douglas PUD, Grant PUD, COE, and the U.S. Bureau of Reclamation), as well as all purchasers and participants of the projects, including the BPA. The Hourly Coordination Agreement sets forth terms for operating the five non-federal mid-Columbia hydroelectric projects and two upstream federal projects, Grand Coulee and Chief Joseph, in a coordinated manner through the "middle" stretch of the Columbia River.

The objectives of the Hourly Coordination Agreement are to: (1) coordinate the hydraulic operation of the projects to optimize the amount of energy from the available water consistent with the needs to both (i) adjust the total actual generation to match the total requested generation, and (ii) operate within all parties' power and non-power requirements; (2) provide flexibility and ease of scheduling generation for the projects through centralized coordinated scheduling and to provide flexibility in scheduling project generation; and, (3) to minimize unnecessary project generation changes, including unit starts and stops to the extent this objective is consistent with the other objectives of the Hourly Coordination Agreement.

Under the Hourly Coordination Agreement, the system's federal and non-federal hydroelectric projects cooperate to efficiently manage Grand Coulee Project flow releases in order to meet the daily demands of power load peaking while maintaining reservoir levels as stable and full as possible. The operating strategy under the Hourly Coordination Agreement includes specific algorithms related to reservoirs for power production, spill prevention, and downstream reservoir refill. In general, spill is avoided unless necessary for fish survival, since it wastes energy. To prevent spill, the total system of projects attempts to meet load by drafting from the project on the system that results in the least head loss. Spill is reduced or prevented where possible, by drafting a project downstream of the point of spill and reducing discharge above the point of spill, if it is anticipated that the drafting project's reservoir can refill within a prescribed time interval. Additional generation produced by the downstream draft is intended to reduce the coordinated request upstream of the point of spill, thereby reducing the inflow to the project being forced to spill. The net effect of this operation is to reduce involuntary spill, where hourly inflow to a project could exceed the hydraulic capacity of the powerhouse, thus forcing the project to spill water. This minimization of spill is desirable from a water quality standpoint, in that it minimizes the occurrence of elevated levels of TDG to only years with high flows and to voluntary spill provided to improve fish survival.

Each project on the system generates the most power when a release from Grand Coulee Project moves into its reservoir. The Project receiving the flow of water moving through the system generates at the highest plant factor necessary to provide as much power as possible, regardless of whether that particular project's customers are making the request at that time. All power requests and non-power requirements are collected and tracked by a computer at Grant PUD's headquarters (Ephrata, Washington) which serves as "Central" to the operation. This computer optimizes movement of water to maximize generation while keeping the reservoirs as full as possible. Participants in the Hourly Coordination Agreement make requests for power from the central system in real time. The computer assigns each project a desired generation level so that all load requests are satisfied in a manner that optimizes the combined operational efficiency of all of the participating projects. This means that a power purchaser with an agreement with the Rocky Reach Project may actually be receiving power generated at Priest Rapids Project at a certain time of the day. The situation may be reversed when it is more efficient to a Grant PUD's purchaser to receive power generated at the Rocky Reach Project. The programming for the computer has evolved through many years of refinements and is intended to achieve the highest overall level of efficiency for the participating projects.

The Hourly Coordination Agreement reduces water level fluctuations that would otherwise occur in both the reservoirs and tailraces of projects, because the higher efficiency is achieved by keeping the reservoirs as full as possible. Most of the mid-Columbia reservoirs have some backwatering (encroachment) effect on the tailrace of the project upstream, and the backwatering also reduces the magnitude of water level fluctuations in the tailwater that result from changes in plant discharge. In the absence of the Hourly Coordination Agreement, the tailwater levels at each plant would fluctuate based on discharge of inflows originating from the Grand Coulee Project, potentially exacerbated by additional fluctuation as individual projects drafted and refilled their useable storage while meeting load requests that are not synchronized with the flow of water through the mid-Columbia River. The Hourly Coordination Agreement prevents compounding effects and actually reduces water level fluctuations by dampening the effect of daily swings in flow releases from Grand Coulee Project.

While the Hourly Coordination Agreement allows participants to take advantage of these resource efficiencies in real time, it also ensures that each participant receives such power benefits in accordance with its rights to the generating assets. The computer keeps accounting records that recognize the varying generation obligations of each participating project. The computer's accounting programming permits the shifting in time of actual generation from one project to another by means of "coordinated exchange." As a result, each project generates when and at the level that is most efficient, and the contractual obligations of each project are met in the most cost-efficient manner possible. A paper account tracks when a project is generating less or more power than it needs to fill its obligations. In any 24-hour period, each project will have generated more than its customers require at certain times of the day and less than its customers require at other times of the day. Over approximately a 24-hour period, there is essentially no discrepancy between a single project's actual generation under the Hourly Coordination Agreement and the customer demand it has worked to fulfill.

2.2.1.2 Role of Rocky Reach and Other Mid-Columbia Projects in Meeting Regional Energy Requirements

Federal hydropower projects throughout the Columbia and especially the Snake River system are subject to many operational restrictions intended to protect fish resources. These restrictions have prevented some projects from fluctuating significantly in order to meet regional power demand. In response, the BPA relies almost entirely on the ability of the mid-Columbia projects to respond to demand through regional load following outlined in the Hourly Coordination Agreement. Essentially, the seven mid-Columbia projects perform all of the load regulation for the Northwest electrical system. The operational restrictions placed on Grant PUD projects through the Hanford Reach Agreement shifts the burden of regional load following even more heavily onto the Rocky Reach and Wells projects.

The main role of the Rocky Reach Project in the Hourly Coordination Agreement is to utilize ramping (change in generation output) to meet the burden of regional load following. However, despite the system's heavy reliance on Rocky Reach's ramping capability, the Project manages to perform this role with the second smallest amount of useable reservoir storage on the system and a maximum reservoir fluctuation of only four feet.

The Rocky Reach project is fulfilling its appropriate role under the Hourly Coordination Agreement from the perspective of both fish and power obligations. It follows load in a manner that cannot be duplicated by the Wanapum and Priest Rapid projects (due to Hanford Reach Agreement considerations), thereby allowing those projects to manage their reservoirs in order to meet obligations for fish. If Rocky Reach were similarly restricted in operation, there would be implications for the entire Northwest electricity market, which would demand replacement power. This could be problematic in other environmental respects, given the amount and likely sources of replacement power. Hydro units are able to adjust to meet load much more quickly than thermal (gas, oil, coal, or nuclear) systems, and much more efficiently. Hydropower units can start and stop quickly, matching load demands on a four-second basis and reducing the need for significant reserves. If the load regulating ability of the mid-Columbia was lost due to restrictions, new generating facilities would need to come online to replace the hydropower system's ability to respond to load on a four-second basis. In order to replace this kind of flexible resource in a manner that would provide sufficient reserves for immediate response to regional load, as much as 2,000 megawatts (MW) of additional thermal generation would be required. These plants would be operated much more inefficiently, have negative air quality impacts and increase greenhouse gas emissions.

2.2.2 Current Operations

Chelan PUD operates the Project's reservoir with a normal maximum headwater elevation of 707. The minimum allowable headwater level is 703, but drafting of headwater below 705 is infrequent (less than 2% of the time). Although the Project has a total useable storage of 36,400 acre-feet between headwater 707 and 703, not all the storage is used, except in an emergency. Standard procedure is to not reduce forebay elevation below 704 because the bottom foot of storage is needed in reserve to maintain stability in the power grid. The reservoir's total useable storage is sufficient to run the plant for about two hours (at average flows) without additional inflows. In normal operations, this storage can be used to increase outflow over the inflow by about 10,000 cfs over a full day.

During a normal water year, the plant operates at a plant factor of 55% (average flows are only sufficient to operate at 55% of the Project's maximum generating capacity). During high water years, the Project operates at a higher plant factor but is also more often subject to spill to pass flows in excess of plant turbine capacity. When operating at a higher plant factor, the Project is able to operate at or near full load for longer periods of time without drafting the storage from the reservoir. Under lower water supply conditions, the number of hours that the plant can sustain operations at or near peak load diminishes.

2.2.3 Hanford Reach Fall Chinook Protection Program

Chelan PUD has participated since 1988 in flow management operations for the protection of fall Chinook salmon that spawn in the Hanford Reach of the Columbia River. These joint operations were originally specified in the Vernita Bar Agreement, which provided protective operations from the beginning of spawning activity (late October) through incubation until the end of the emergence period (late April to early May). The Vernita Bar Agreement was scheduled to expire in 2005, concurrent with the expiration of Grant PUD's license for the Priest Rapids Project.

Research in the late 1990s found that flow fluctuations in the Hanford Reach can also adversely affect survival of fall Chinook fry during the first few weeks after emergence. Due to the extensive areas of backwater channels and shallow gravel bars in the Hanford Reach, changes in river elevation associated with daily and weekly flow fluctuations can cause fish to be stranded in areas where they are exposed to mortality from dewatering, or heat stress and predation in shallow pools that become isolated from the main river channel. To address these issues, Chelan PUD has voluntarily cooperated with Grant PUD, BPA and Douglas PUD to enable Grant PUD to operate the Priest Rapids Project to reduce flow fluctuations. These voluntary operations, initiated in 1999, included research covering alternative operating methods that resulted in development of a long-term operating plan has replaced and improved upon the Vernita Bar Agreement.

The new agreement, the Hanford Reach Fall Chinook Protection Program Agreement (Hanford Reach Agreement), Appendix C, has been executed by most of the original parties to the Vernita Bar Agreement. In addition to Chelan PUD, this new agreement includes the following parties; Grant PUD, BPA, Douglas PUD, WDFW, NOAA Fisheries, and the CCT. The new agreement includes operations for the protection of fall Chinook salmon from the beginning of spawning through the early rearing period when Chinook fry are susceptible to stranding. The new agreement requires the same actions from Chelan PUD as the original Vernita Bar Agreement, but includes the additional time period that extends from April into June. This includes supporting Grant PUD's operations through the Hourly Coordination Agreement and providing up to one foot of draft from Rocky Reach Reservoir. Grant PUD has submitted the new Hanford Reach Agreement to the FERC as part of its application to relicense the Priest Rapids Project. Under the terms of the Hanford Reach Agreement, the parties have implemented the agreement pending action by FERC.

2.2.4 Anadromous Fish Agreement and Habitat Conservation Plan (HCP)

A 50-year agreement regarding protection of anadromous salmon and steelhead at the Project has been incorporated into the Project's existing license and will be the incorporated into the new license for the Project. The Project has special operations and facilities that are used to meet the survival objectives of the HCP, which are 93% survival for juveniles passing the Project and 91% combined survival of juvenile and adult salmon and steelhead passing the Project. Operations for the Project under the HCP use the juvenile fish bypass system, installed in 2003, as the primary method for safely passing juvenile salmonids. Under the HCP, Chelan PUD continuously operates the juvenile fish bypass system from April 1 to August 31 each year. The spillway is also used, when needed to supplement the juvenile bypass system, to provide a safe passage route. Spill levels are set by the HCP Coordinating Committee based on results of a 2003 juvenile fish passage efficiency study and ongoing survival studies. Due to the performance of the juvenile bypass system in passing yearling Chinook and steelhead, spill is not currently needed to meet survival standards for these species. Spills will continue to be used for passing sockeye and subyearling Chinook salmon until such time that the juvenile bypass system or other tools for improving fish survival have met the survival standards. Spill, when required, is provided over a time period that encompasses 95% of each species' downstream migration. Spill levels in 2004 were 24% and 9% of the estimated daily average flow for sockeye and subyearling Chinook, respectively. Spill in 2005 will be provided on alternating days for sockeye in order to evaluate its effect on sockeye passage rates through the juvenile bypass system. After completion of survival studies, spill will supplement the juvenile bypass system as necessary to achieve the survival standards. Spill is managed to reduce adverse effects on water quality and meet water quality standards for TDG.

In addition to the use of the juvenile bypass system and spill to pass juvenile salmon and steelhead, the spillway and powerhouse are operated to promote upstream passage of adult fish via the upstream passage fishways. These operations include spillgate sequences that are believed to help fish find the fishway entrances and powerhouse turbine loading preferences for the same purpose. The powerhouse turbine loading is also adjusted to promote juvenile salmon and steelhead passage through the juvenile bypass system during its operating season.

2.2.5 Continuation of Beneficial Operations

The agreements that have been discussed, and other treaties, agreements and federal decisions that affect the Project's operations, establish the environmental setting for Columbia River flows that determines how the Project affects water quality and associated beneficial uses that are dependent on water quality and aquatic habitat. In order to predict the future of the Project's compliance with water quality standards, it is necessary to be assured that the Columbia River flow management and the Project's operations that are necessary today to meet water quality standards will continue into the future. In other words, there is a need for assurance that should agreements expire, new agreements or other mechanisms will, at a minimum, maintain the water quality and aquatic habitat levels that currently exist. There is little reason to believe that there will be any steps backward in water quality compliance in the future. The HCP specifically states that, should the agreement terminate, the measures previously agreed to by the parties shall remain in effect. In addition, the Project's new license will contain articles that require the Project to maintain measures that have been necessary components of the HCP and Hanford Reach Agreement for the protection of anadromous salmon and steelhead. Similarly, regulations that govern operation of the FCRPS will continue to support water quality and protection of aquatic resources. The effective actions in agreements that promote efficient power generation, such as the PNCA and the Hourly Coordination Agreement will also continue into the future since no parties are likely to desire reduced efficiency. A more detailed discussion of these agreements and other major agreements, including their expiration dates and affects on Project operations, is contained in Appendix A.

2.3 Water Quality Background Conditions

The water quality of the Rocky Reach Reservoir was assessed to determine if these waters were in compliance with the 1997 Washington State Water Quality Standards for Class A waterbodies. The assessment included basic limnological information on productivity. The sampling was conducted from October 1999 to September 2000 (water year 2000). The results, which included assessment of water quality parameters, plankton, and attached benthic algal sampling, are reported in Parametrix and Rensel, 2001, and summarized in the Preliminary Draft Environmental Assessment (PDEA) (Chelan PUD, 2004). The objectives of this study were to: compare existing water quality to the water quality standards; identify the appropriate methods and approach for monitoring key parameters; relate the monitoring results to fisheries concerns and other uses of the reservoir; compare and contrast results to upstream and downstream conditions from other studies; and to determine the nature of any ongoing project-related impacts to water quality. A summary of the findings of the water quality assessment follows.

2.3.1 Upstream Water Sources Establish Background Water Quality

The water quality of the Rocky Reach Reservoir is primarily influenced by the water quality arriving from upstream sources. The Rocky Reach Reservoir is a run-of-the-river reservoir of approximately 8,235 surface acres at 100,000 cfs (maximum 9,860 acres at flood flows). Its 43-mile length is second longest among mid-Columbia River reservoirs behind Rufus Wood Lake, created by Chief Joseph Dam. However, due to its narrow width, the Rocky Reach Reservoir is one of the smallest in total volume of the seven mid-Columbia River reservoirs. The average depth is approximately 42 feet, with a maximum depth of about 180 feet. The water retention rate varies from less than one day at high flows to over three days at low flows, and averages about 1.8 days. This is a very low retention rate for a reservoir, but typical of other mid-Columbia run-of-the-river reservoirs that have similarly low water retention rates when compared to storage projects (Rensel, 1993). The source water for Rocky Reach Reservoir is the Wells Reservoir, which receives flow from Chief Joseph Dam (Lake Rufus Woods) and the Methow and Okanogan Rivers. The primary influence on water quality from Lake Rufus Woods is the limnology of Lake Roosevelt, which is formed by Grand Coulee Dam. Lake Roosevelt is a major storage reservoir with a mean retention time of well over one month. The operation of Lake Roosevelt has a major influence on not only water quality, but biotic qualities of downstream reservoirs such as the supply of phytoplankton and zooplankton stocks (Beckman et al. 1985, Stober et al. 1981).

2.3.2 Summary of Water Quality Parameters in Compliance with Numeric Standards and Criteria

The Rocky Reach Project generally has no adverse effect on the objectives and narrative requirements of the water quality standards. The Project and its reservoir maintain the water quality, habitat and accessibility necessary to support all the existing beneficial uses included in the standards for Class A waterbodies. These uses include primary contact recreation, aesthetic enjoyment, sports fishing, boating, water supply for domestic, industrial and agricultural uses, and fish and wildlife habitat, including habitat for spawning, rearing and migration of cold-water salmonid species. The Rocky Reach Reservoir has clean, clear water with high water transparency, very low fecal coliform content, and high DO concentrations.

The Rocky Reach Reservoir meets water quality standards numeric criteria for DO, pH, turbidity, and fecal coliform (Chelan PUD 2004, Table 7 in PDEA). The mid-Columbia River, including the Rocky Reach Reservoir, is currently listed as impaired for TDG and water temperature with five sites on or near the Rocky Reach Hydroelectric Project reservoir that are listed in the 2002/2004 candidate list (Section 303(d) of the Clean Water Act). Water comes into the reservoir at times with temperatures or TDG levels that exceed the numeric criteria. The existence of the Project does have the potential to increase water temperatures during the summer due to the effects of the reservoir on total water surface area and travel time of water moving through the reservoir. Spill operations at the Project can increase TDG levels in the Columbia River below the Project. The effect of the Project on these parameters is discussed in greater detail in separate sections.

2.3.2.1 Dissolved Oxygen

The water quality standards for DO state that concentrations "shall have a one-day minimum 8.0 milligrams per liter (mg/L)". All measurements taken in the Project's reservoir complied with that standard (Figure 2). Increasing DO concentrations were measured from upriver to downriver each month. The lowest DO measured in water year (WY) 2000 was 8.26 mg/L in September at the Wells Dam tailrace. Average DO concentrations were commonly over 10 mg/L for all categories of stations. The DO levels increased as water moved downstream through the reservoir and the same increasing trend was observed, for all months except May, when comparing DO at the Rocky Reach Dam tailrace to the Wells Dam tailrace. These differences averaged 0.35 mg/L for all months, with largest differences in October, February, and May. Generally, littoral DO concentrations were greater than at pelagic stations, but the average differences were less than 0.15 mg/L. One-meter DO monthly profiles show little variability among categories (littoral, pelagic or tailrace) of stations.

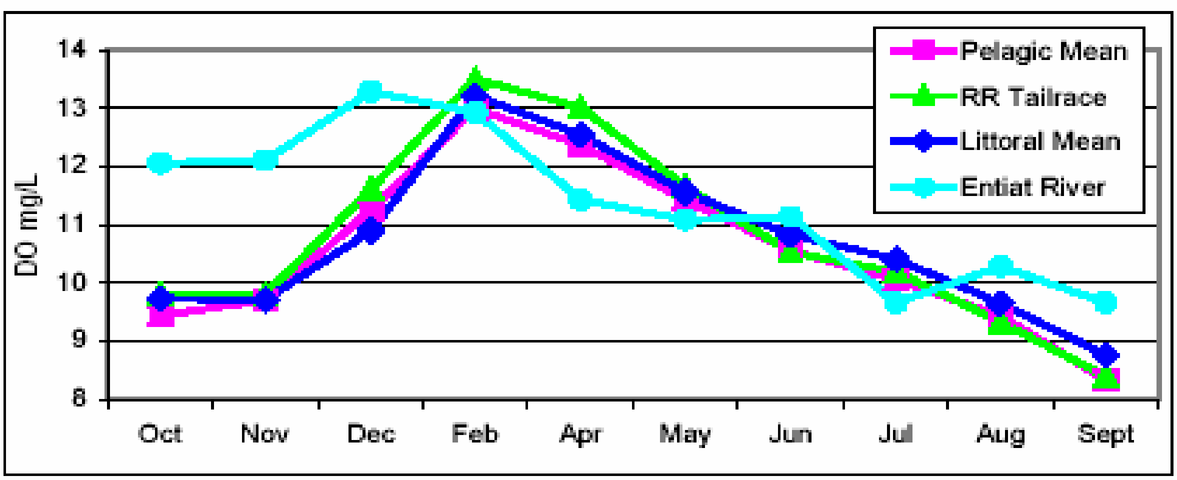


Figure 2: Dissolved Oxygen Profiles for Categories of Stations from Rocky Reach Reservoir and the Entiat River, WY 2000 (Parametrix and Rensel 2001)

2.3.2.2 pH

The water quality standards for pH state that "pH shall be within the range 6.5 to 8.5 with human-caused variation within the above range of less than 0.5 units". A similar standard exists for Class AA waters but only 0.2 units of variation are allowed due to human causes. Those standards were met for Rocky Reach Reservoir during this study. Littoral stations had slightly higher pH compared to pelagic stations, beginning in spring and more so in summer (Figure 3). Higher pH near shore could be attributed to photosynthesis of macrophyte populations that typically have peak biomass in August. Rensel (1993) previously found that the mid-Columbia River's average annual pH ranges from about 7.5 to 8.1 at Grand Coulee Dam and about 7.5 to 8.3 at Rock Island Dam. Summer pH was similar, but showed more variation. Rocky Reach WY 2000 pelagic station measurements were virtually the same, ranging from 7.7 to 8.1.

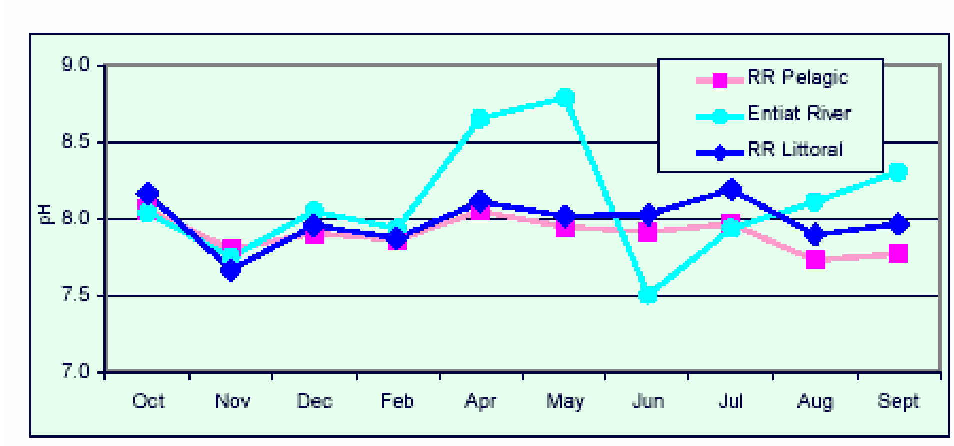


Figure 3: Plot of Monthly pH at 1-m Depth from Selected Stations, Water Year 2000 (Parametrix and Rensel 2001)

2.3.2.3 Turbidity

The water quality standards for turbidity allows for no more than a 5 nephelometric turbidity unit (NTU) increase over background when background turbidity is 50 NTU or less and a 10% increase in turbidity when the background turbidity is more than 50 NTU. Turbidity was very low at all times and locations during WY 2000, averaging 1.9 to 2.2 NTU, depending on the category of the station. Maximum turbidity was noted during peak flows in April and May, but not exceeding 3.3 NTU. Low turbidity in the mid-Columbia River is in part a byproduct of large upstream storage reservoirs that allow all but the finest solids to settle out. The survey did not detect any significant Project-related sources of turbidity (Parametrix and Rensel, 2001).

2.3.2.4 Fecal Coliform

The water quality standards for freshwater state that fecal coliform "shall both not exceed a geometric mean value of 100 colonies/100 milliliter (ml) and not have more than 10% of all samples obtained for calculating the geometric mean value exceeding 200 colonies/100 ml." Fecal coliform samples were collected at three pelagic stations in Rocky Reach Reservoir. Levels of fecal coliform were well within the above criteria, ranging from 1-10 colonies and averaging

2.7, 1.5, and 1.5 colonies from sampling stations at Beebe Bridge, Rocky Reach forebay and tailrace, respectively. Results of the sampling show very low or undetectable results at all times except in November and December (10 colonies at Beebe Bridge) when levels were slightly elevated. The cause of this minor elevation was unknown, but larger numbers of ducks and geese on or near the reservoir were evident during this time period (Parametrix and Rensel, 2001).

2.3.3 Reservoir Limnology Supports Class A Beneficial Uses

The water quality standards requirements for Class A waterbodies do not have specific numeric criteria regarding nutrients and other limnological characteristics. However, the limnology of the Rocky Reach Reservoir is supportive of Class A beneficial uses (clear and clean for recreation, trophic level consistent with cold water aquatic life uses). Parametrix and Rensel (2001) reported that lake enrichment classifications suggest the Rocky Reach Reservoir water column would be rated “lower mesotrophic” or on the low end of moderately enriched. The Trophic State Index (TSI) is an indication of the degree of enrichment of a lake using measurements of water transparency (Secchi disk depth), total phosphorus concentrations and chlorophyll-a concentrations during the summer (June to September) months. The TSI rating must be qualified, as the system is more suitable for lakes with longer retention times and turbidity due to plankton, not solids. There are no highly suitable rating systems for mid-Columbia River reservoirs. By TSI component, Rocky Reach Reservoir is oligotrophic with respect to water clarity but mesotrophic with respect to total phosphorus and chlorophyll-a concentrations. This trophic level is consistent with the limnological characteristics of other Columbia River reservoirs.

Transparency averaged 6.4 meters (m) in the summer months, steadily increasing from June to September in a pattern seen in other mid-Columbia River reservoirs (Parametrix and Rensel, 2001). Total phosphorus, a widely used indicator of trophic state, averaged 18.7 micrograms per liter (µg/L) at pelagic stations in the summer, and was positively correlated with hourly flow during sampling. Orthophosphate concentrations were minimal year-round, and during the summer averaged only 1.7 µg/L, similar to upstream conditions and below the detection limits of many laboratories. This measure is only a general indicator of trophic state, as phosphorus cycles quickly and true nutrient depletion for algal growth must be determined by other means. Ratios of dissolved inorganic nitrogen to orthophosphate (N:P ratios) were very high at all times, suggesting the possibility of summer phosphorus limitations to primary productivity and indicating that nitrogen concentrations were relatively high (Parametrix and Rensel, 2001).

Parametrix and Rensel (2001) reported that biological productivity in the Rocky Reach Reservoir was similar to other mid-Columbia River reservoirs. Chlorophyll-a concentrations ranged from relatively low to moderate during WY 2000. During the late fall and winter levels were less than about 2.5 µg/L and from April onward were somewhat higher. April through July samples reflected average concentrations slightly less than 4 µg/L. Overall chlorophyll-a concentrations increased only very slightly within the reservoir, averaging 0.15 µg/L greater in the pool than at the Wells Dam Tailrace. Rocky Reach tailrace had lower concentrations than pelagic stations in the reservoir.

Upstream measurements of chlorophyll-a in Rufus Wood Lake during the summer of 2000 averaged 1.9 µg/L but downstream at the Brewster Bridge in Lake Pateros and throughout Rocky Reach Reservoir pelagic stations increased to approximately 3 µg/L. Summer mean chlorophyll-a in Priest Rapids Dam area in 1999 was also about 3 μg/L, with little variation among months (Normandeau Associates 2000).

Littoral attached benthic algae in Rocky Reach Reservoir was high with the overall mean of 89.7 milligrams per meters squared (mg/m^2) monochromatic chlorophyll-a in the eutrophic range. Values were in the range of the mesotrophic/eutrophic lower Snake River. Attached benthic algae peaked in April; annual lows were in August.

Diatoms were the dominant phytoplankton species in terms of abundance and biovolume in the water column, followed by cryptophytes (small unicellular flagellates) and representatives of several other major taxa. In freshwater lakes of the northern hemisphere and many other places of the world diatoms are considered desirable because of their value as food sources for the rest of the aquatic food web. Total phtytoplankton biovolume was relatively large all year, with a prolonged spring peak and a lower summer stanza. No prolonged differences were seen among stations or types of stations. Overall, the biovolume of phytoplankton in these results was high compared with other regional (non-mainstem) lakes or reservoirs.

Zooplankton biomass was dominated by rotifers in most months. Crustacean zooplankton was relatively scarce compared to regional lakes that are truly mesotrophic, but within the abundance or biomass range found in downstream reservoirs in recent years. Large biovolume and relative size of the preferred fish prey species Daphnia were observed from July to September. Lower biovolume and mean size of Daphnia was noted at other times. There were no pronounced differences among biomass estimates for pelagic and littoral stations, with the possible exception of lower to mid reservoir areas in the fall of 1999 and summer of 2000.

In summary, the limnology of the Rocky Reach Reservoir has the appropriate nutrient levels, biological productivity and availability of fish food organisms to support native coldwater and cool-water fish communities. There is no indication of nutrient enrichment or other anthropogenic changes to limnological factors that degrade the water quality or otherwise impair the reservoir's ability to provide suitable habitat and food sources for support of balanced indigenous populations of aquatic organisms.

2.4 Total Dissolved Gas

2.4.1 Water Quality Standard for TDG

The mid-Columbia River, including the Rocky Reach Reservoir and tailrace, is listed as impaired for exceedances of TDG numeric criteria. The water quality standards for TDG is "Total dissolved gas shall not exceed 110% of saturation at any point of sample collection," with an exception for flood conditions and a special condition for fish passage at Columbia River dams. The water quality criteria established for TDG does not apply when the stream flow exceeds the seven-day, ten-year frequency flood (7Q10), and the TDG criteria may be adjusted to aid fish passage over hydroelectric dams when consistent with a gas abatement plan approved by the WDOE. The gas abatement plan must be accompanied by fisheries management and physical and biological monitoring plans.

The special fish passage criteria for the Snake and Columbia rivers apply when spilling water at dams is used to aid fish passage. The fish passage allowances for TDG are: The TDG level must not exceed an average of 115% as measured in the forebay of the next downstream dam and must not exceed an average of 120% as measured in the tailrace of each dam (these averages are measured as an average of the twelve highest hourly readings in any one day, relative to atmospheric pressure); and a maximum tailrace TDG one hour average level of 125% must not be exceeded.

2.4.2 Total Dissolved Gas Levels Measured in Project Waters

2.4.2.1 Historical Overview

Chelan PUD has been spilling water for downstream fish passage at the Rocky Reach Hydroelectric Project since 1976. Spill is a tool used for improving survival of anadromous salmonids during their downstream migration and is part of the "tool box" being implemented to meet HCP survival standards. Spill can also occur when high stream flows exceed the hydraulic capacity of the powerhouse or, occasionally, when energy demand is low and river flows are high. In the Columbia River basin, a regional effort has been undertaken to monitor and control TDG and its biological effects. Chelan PUD has participated in that regional effort since 1982.

Monitoring of TDG was only at a forebay station from 1982-1995. Chelan PUD upgraded monitoring of TDG levels in the forebay and attempted to add a site below the tailrace of the Rocky Reach Hydroelectric Project in 1996 in order to voluntarily comply with the terms of the special condition for fish passage. The tailrace monitoring site, a barge anchored mid-river, could not be kept anchored under high flows. In 1997, the DFMS was established approximately four miles downriver at the Odabashian Bridge on Highway US 97. In the majority of the historical documents, this location was referred as the tailrace. Under current TDG abatement plans, the DFMS has been used to represent the tailrace; however, future compliance requirements may mandate that the monitoring site be moved much closer to the spillway. When historical information is referenced, the term DFMS will be used (in place of the terminology in the original document) when data from this monitoring location is cited. The study methods and results for the initial physical monitoring programs conducted to voluntarily meet the special condition requirements are reported in McDonald and Priest (1997) and Koehler and McDonald (1997, 1998). The Project conducted fish spill annually to provide fish passage in accordance with FERC requirements. The TDG study objectives at that time were to:

(1) determine if the Chelan PUD's fish spill program was in compliance with the special condition requirements for supersaturation;
(2) examine possible relationships between the percent of total river flow spilled and total volume spilled on changes in TDG levels; and
(3) verify that TDG levels recorded by the DFMS were representative of the entire tailrace flow.

The level of TDG present in both the forebay and at the DFMS has varied from year to year, depending on the streamflow, operations at upstream hydroelectric projects, and the amount and manner of spill at Rocky Reach Dam. TDG levels in the forebay and at the DFMS also vary throughout the spring and summer within the same year. This variation was mostly attributable to incoming TDG levels associated with projects upstream and, in part, to changing spill volumes at Rocky Reach. The highest flows and spill levels experienced since the completion of upstream storage projects occurred in 1997 (Figure 4). TDG levels recorded in 1997 were the highest recorded at Rocky Reach Dam since monitoring began at the DFMS. (Figure 5).

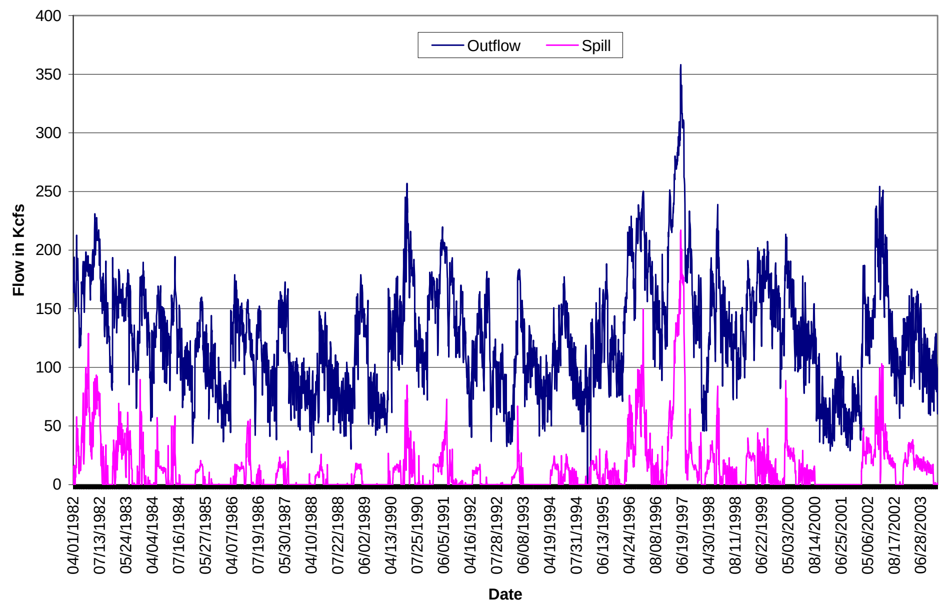


Figure 4: Total Outflow and Spill Discharge at Rocky Reach Dam, 1982-2003

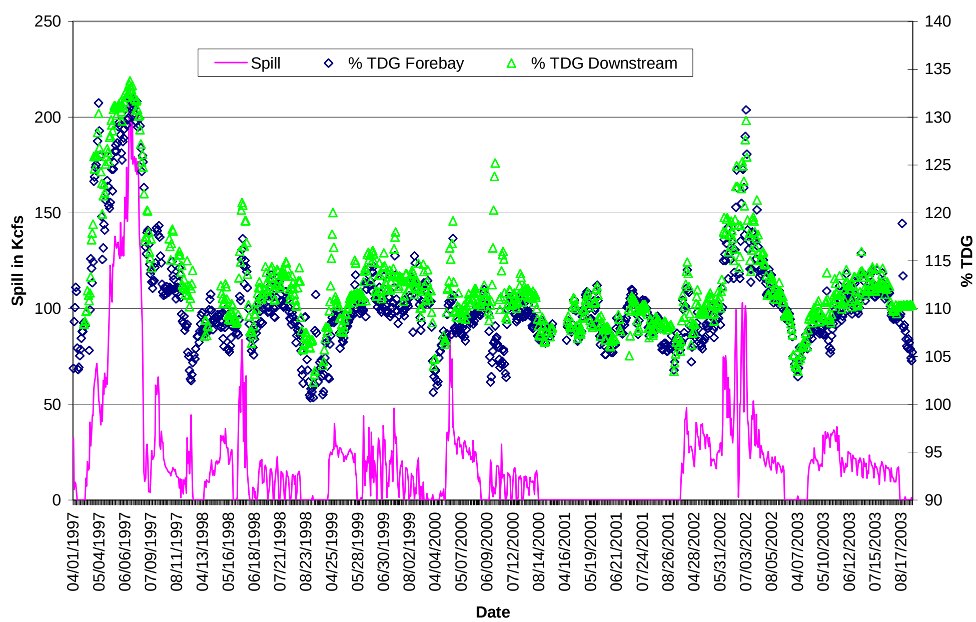


Figure 5: Rocky Reach Spill Discharges and Percent TDG Measured in the Forebay and at the DFMS, 1997-2003

The level of TDG measured at the Rocky Reach DFMS from 1996-1998 was primarily the result of high TDG levels arriving in the Project forebay, rather than a result of spill operations at the Project. McDonald and Priest (1997) and Koehler and McDonald (1997, 1998) used regression analysis to evaluate the relationship between the change in TDG levels from forebay to at the DFMS and the total volume spilled in kilo cubic feet per second (kcfs), as well as percent of river spilled. Data were stratified by spring and summer. Generally, the effect on TDG level did not correlate with either total volume spilled or percent of river flow spilled, except during the spring of 1998 when moderate causal relationships were determined (correlation coefficient r^2 = 0.5 for total volume spilled and r^2 = 0.41 for percent of flow spilled). These relationships did not hold for 1997 nor summer 1998 data. As seen in Figure 5, during the high flows in 1997 the TDG levels coming into the Rocky Reach Hydroelectric Project forebay were high and likely above the equilibrium level for TDG entrainment in the Rocky Reach Project spillway. The Project's spill operations appeared to have reduced TDG levels at times in 1997.

Transect measurements near the Rocky Reach Project DFMS consistently indicated highest readings in the east channel, with a downward gradient in TDG levels in the direction of the west channel. Koehler and McDonald (1997) found a gradual descent in TDG with distance downstream from the Project during high spills in 1997, but a similar trend was less apparent in 1998 when spill volumes were lower (Koehler and McDonald, 1998). The downstream monitoring location at the Odabashian Bridge (the DFMS) was placed in a location representative of the average TDG level across the river channel. Transect measurements over the past four years typically find that TDG at the DFMS is within 1-2% TDG of the highest level measured during the transect.

Comparison of forebay to DFMS data showed an increase in TDG levels even when there was little or no spill. Although TDG levels generally increased with greater spill, the increase in TDG from forebay to DFMS when no spill occurred leads to the conclusion that factors other than spill may also influence TDG, or there are potentially undetected vertical and/or horizontal gradients in TDG across the river which are not accounted for with a fixed station monitor.

2.4.2.2 TDG Analysis 1997-2000

Early in the relicensing process, Chelan PUD funded a review of TDG monitoring and project operations data for the years 1997-2000. This study (Parametrix, 2000), which was submitted to the Natural Sciences Working Group for review and comment, examined the relationships between incoming levels of TDG, total flow, spill volumes and spillgate configurations at Rocky Reach, and the levels of TDG recorded at the downstream monitoring site and at the forebay of Rock Island Dam. The analysis of monitoring data determined that spill at Rocky Reach Hydroelectric Project has a lower TDG entrainment effect than is observed at most other Columbia River projects. Parametrix (2000) concluded: "Spill at Rocky Reach dam only produces minor increases in TDG levels. During the years of 1998-2000 TDG levels increased only slightly during the spill period (1-3% of saturation on average, range –5% to +15%). Average TDG levels during 1998-2000 remained below 110% of saturation, although point measurements ranged from 100% to 120% of saturation. These conditions occurred with total river flows ranging from less than 100,000 cfs to about 275,000 cfs. Increases in TDG levels were only slightly greater at higher river flows."

The analysis determined that the TDG level below the Rocky Reach Hydroelectric Project is more influenced by the TDG level arriving at the Project than by the level of spill at the Project, confirming the earlier observations from the annual reports between 1996 and 1998. During the high flow and high spill conditions in 1997, the spill at the Project did not increase the mean TDG level above the TDG level of water arriving at the dam. The variation in the change in the TDG concentration over the Project was substantial, depending primarily on the incoming TDG concentration, not on the total flow rate (Figure 6). However, the incoming TDG concentrations to the forebay of the Project tended to be higher with higher water flow, lending to higher concentrations at the DFMS.

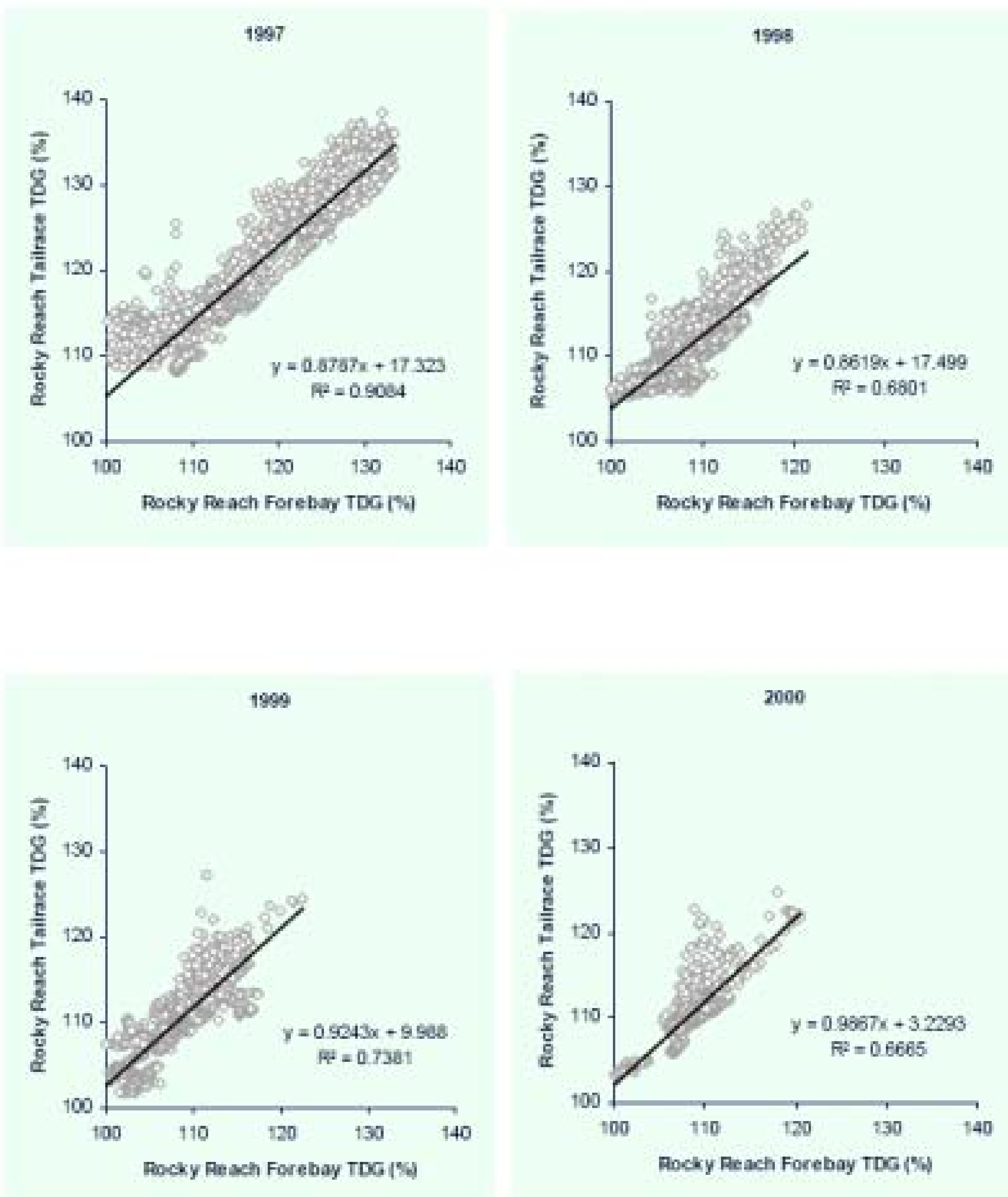


Figure 6: Change (Delta) in Percent TDG Relative to Total River Flow at Rocky Reach Dam 1997, 1998, 1999, and 2000

The analysis indicated that different types of spill operations can affect the entrainment of air and resultant TDG level. Parametrix (2000) reported: "Evaluations of different spillgate configurations used at Rocky Reach dam suggest that configurations using a greater number of gates tend to minimize the increases in TDG from the forebay to the tailrace [DFMS]." The analysis could not give a more precise description of the difference in TDG increases for different gate configurations due to the confounding effects of the levels of TDG arriving at the project and the variability in the degree of mixing between powerhouse flows and spillway flows at the downstream sampling location. The analysis also determined that TDG levels dissipate somewhat when traveling through the Rock Island Hydroelectric Project reservoir, with more reduction in TDG at lower flows than higher flows (Parametrix, 2000).

2.4.2.3 <u>TDG Operations and Reduction in Exceedances</u>

The analysis of TDG levels with different spillgate settings and at different spill levels has been used by Chelan PUD to refine operations to achieve fish survival objectives, while reducing TDG levels. As noted in the Parametrix (2000) report, the exceedances are not typically observed at the Project DFMS during spill unless they were present in the forebay. The level of TDG arriving at the Project has the greatest influence on the level of TDG both at the DFMS and arriving at the forebay of Rock Island Dam, particularly when the TDG level is high. Chelan PUD has recorded statistics on exceedances of the TDG standards since 1997 (Table 1).

Table 1: Total TDG Exceedance Record for Rocky Reach Dam

Year	RR Forebay (> 115%)	RR Tailrace* (> 120%)	RI Forebay (> 115%)	Notes – All exceedances based on the average of the highest 12 hours recorded in a day
1997	83	69	75	All exceedances in Rocky Reach Tailrace* and Rock Island Forebay were coincidental with exceedance TDG levels arriving at Rocky Reach from upstream dams.
1998	6	5	9	
1999	2	1	1	
2000	1	2	1	
2001	0	0	0	No Spill at Rocky Reach or upstream projects
2002	43	25	48	Only 6 Rock Island Forebay exceedances were not coincidental with exceedance TDG levels arriving at Rocky Reach from upstream dams
2003	5	0	3	
2004	0	0	0	No HCP spill needed until May 6.

* Tailrace measurements were made at the DFMS.

As noted in Table 1, in both years with high numbers of exceedances (1997, 2002), the level of TDG was already high in the Columbia River as it entered the Rocky Reach Project. Columbia River flows were also high, exceeding 200,000 cfs during the times the majority of exceedances occurred, and frequently exceeding the 7Q10 flow. When the TDG level of water reaching the forebay exceeds the 115% criterion, as in 1997 and 2002, the additional spill from the Rocky Reach Project generally does not result in an increase in TDG at the Rock Island Project's forebay. This is evident in Figure 7 and Figure 8, where it can be seen that the Rock Island forebay TDG levels were generally lower than or about the same as the TDG levels in the Rocky Reach forebay, despite high spill volumes at Rocky Reach. When TDG levels in the Rocky Reach forebay exceed 120%, the spill operations at Rocky Reach generally reduce the TDG level arriving at Rock Island forebay, as was seen in 1997 and 2002 when the TDG level arriving at Rocky Reach was greater than 120%. Thus, during high flow periods approaching the 7Q10 flow, the Rocky Reach Project either has no net effect or may even reduce the TDG level in the Columbia River, as measured at the DFMS and the forebay of the Rock Island Dam.

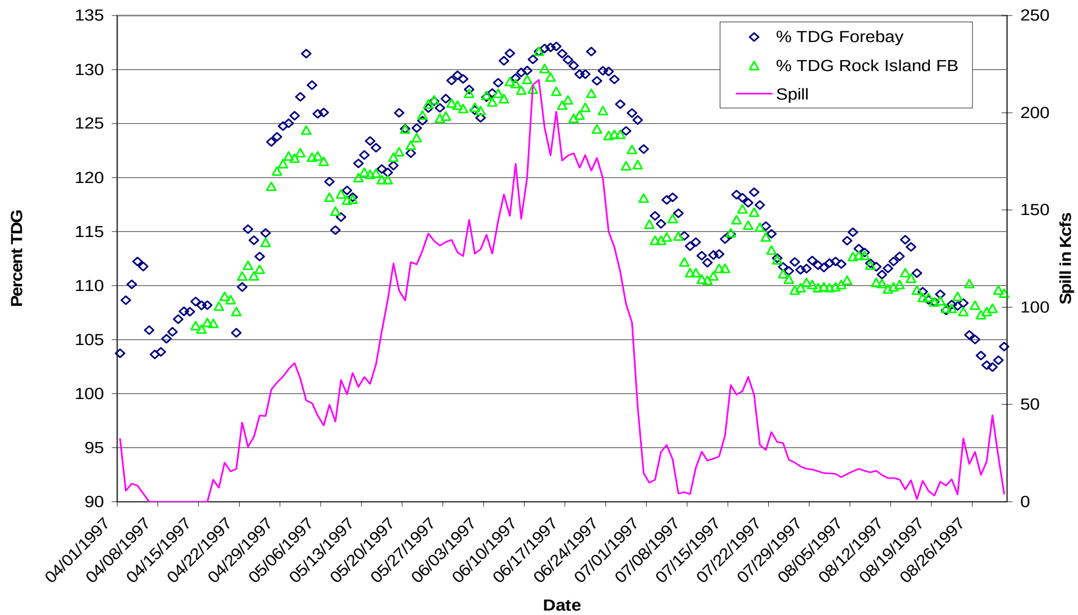


Figure 7: TDG Levels in the Rocky Reach and Rock Island Project Forebays in 1997

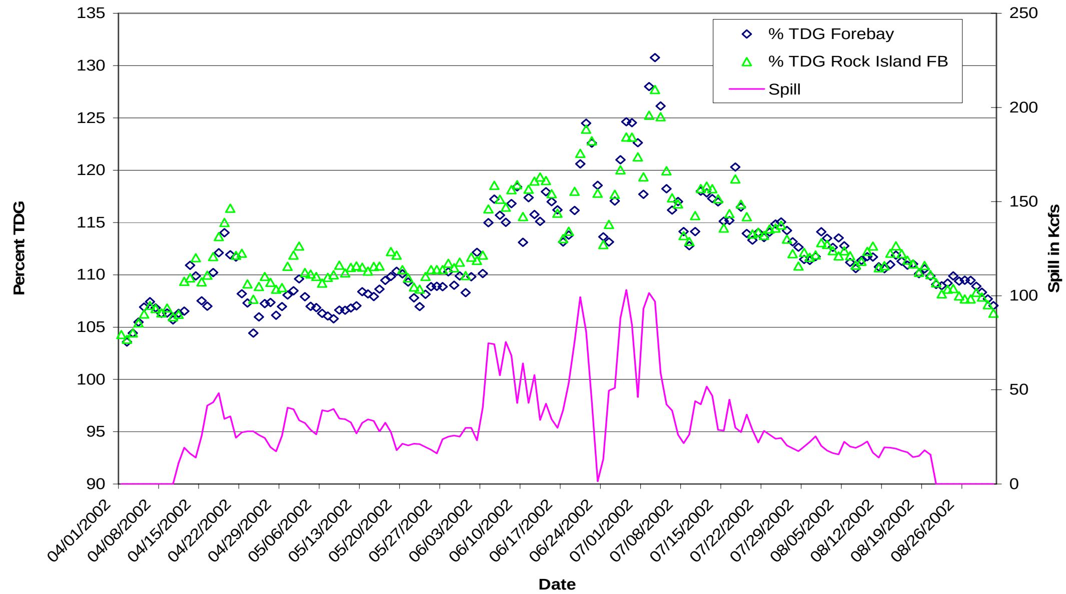


Figure 8: TDG Levels in the Rocky Reach and Rock Island Project Forebays in 2002

The contribution of the Rocky Reach Project to TDG exceedances has been very low during the past eight years. When the forebay TDG level arrived at or below 115%, the additional TDG levels caused by the spill at Rocky Reach Dam rarely exceeded the criteria for the fish passage special condition. From 1997-2004, there were 140 exceedances of TDG in water arriving at the Project's forebay (Table 1). Although Rocky Reach was also spilling, the number of exceedances was lower at the Rocky Reach Project DFMS (tailrace; 102) and at the Rock Island Project's forebay (137) despite the high TDG levels arriving at the Project.

Table 2 shows the number of times that criteria downstream from the Project have been exceeded when TDG levels arriving at Rocky Reach were no more than 1% above the 115% criterion for the Project's forebay. There were only 11 exceedances of the 120% tailrace criterion and 17 exceedances of the 115% Rock Island Dam forebay criterion that were caused by the Project's spill operations. The other exceedances in Table 1 were all caused by the high TDG levels arriving at the Project and would have occurred even if the Project had not been spilling. Since construction in 2003 of the juvenile bypass system, voluntary fish spill has not caused any exceedances below the Project even though there were five exceedances of 115% criterion in water arriving at the Project's forebay in 2003.

Table 2: TDG Exceedances Caused by Spill at Rocky Reach Dam

Year	RR Tailrace* (> 120%)	RR Tailrace* (> 125%)	RI Forebay (> 115%)	Notes – 120% and 115% exceedances based on the average of the highest 12 hours recorded in a day. The 125% exceedance is for a single hour.
1997	0	0	0	Incoming TDG high at all times
1998	5	3	9	
1999	1	1	1	
2000	1	1	1	
2001	0	0	0	No Spill at Rocky Reach
2002	4	1	6	Incoming TDG level almost always > 115%
2003	0	0	0	HCP spill 25% of daily flow for sockeye, 15% in summer
2004	0	0	0	No HCP spill needed until May 6.

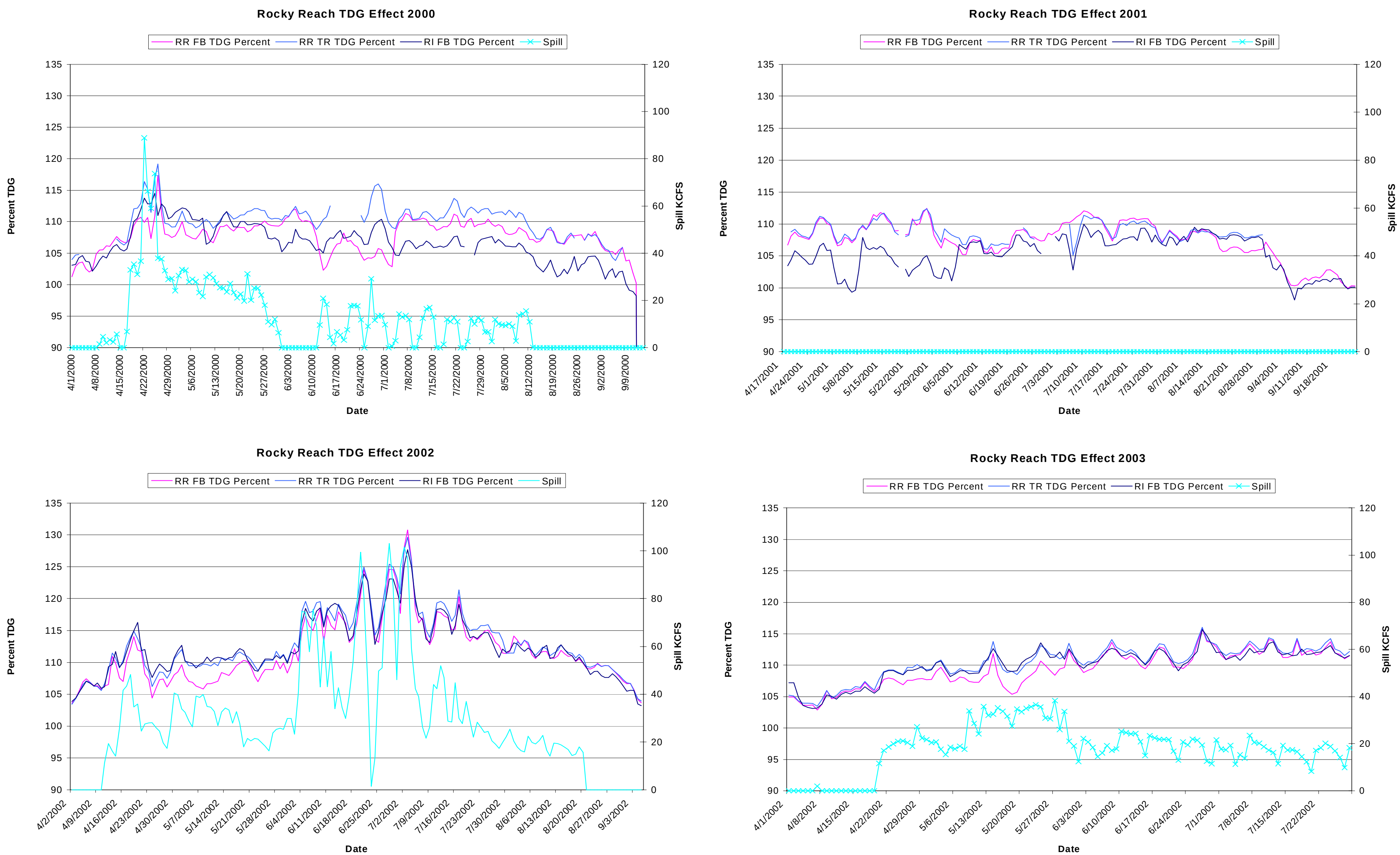
* Tailrace measurements were made at the DFMS.

The improvement in TDG compliance, as well as TDG management in general, is evident by comparing TDG levels 1998-2000 to 2003-2004. The level of voluntary spill provided to meet HCP fish survival standards increased in 2003. Fish passage spill prior to 2003 averaged 15% of total river flow in spring and 10% in summer, whereas spill levels in 2003 included 21 days of spring spill at 25% of total river flow and a 15% spill level from early June to late August. Despite increased spill levels in 2003, TDG levels at the Rocky Reach DFMS and arriving at Rock Island Dam forebay remained near 110% until the 25% spill level began, mostly stayed below 113% through May, and then closely mirrored the level of TDG arriving at the Rocky Reach forebay through the summer. In contrast, Rocky Reach spill operations in 2000 tended to have higher TDG levels in the Rocky Reach tailrace at the DFMS than in the Rocky Reach forebay during the summer, even though the spill level was lower (Figure 9). These results are a direct effect of the TDG levels in the forebay of the Rocky Reach dam.

Fish passage spill was reduced in 2004, based on the efficacy of the juvenile fish bypass system. There were no TDG exceedances in 2004, since the TDG level arriving at Rocky Reach Dam never exceeded 115% and spill management procedures maintained low TDG levels at the DFMS. The 2004 spring spill operations at the Project, where an average of 24% of the river flow was spilled, only increased TDG levels at the DFMS by an average of 2.4% over forebay levels (range 0% to 3.5%). The hourly DFMS TDG level never exceeded 113.1%, well below the 120% criterion. Summer spill of 9% of the river flow, which began June 7 and ended August 21, resulted in an average increase in TDG level of only 0.7% (range -0.2% to 1.5%). The TDG level at the DFMS never exceeded 114.6%, even though TDG level from upstream projects reached 114.3% in the Rocky Reach forebay.

The benefits to water quality of the HCP's outcome-based approach to meeting fish survival goals are evident in the past two year's decisions on spill levels. Rather than "spilling to the gas cap" to meet fish survival objectives, the juvenile bypass system was constructed and studies are underway to optimize its effectiveness in meeting the survival objectives. Studies in 2004 demonstrated higher fish survival for fish that used the juvenile bypass system compared to fish using other passage routes, including the spillway. In 2005, studies are planned to evaluate the effect of spill on juvenile bypass system passage efficiency, as well as the relative contribution of spill to meeting the survival objective for sockeye. The results of these 2005 studies may lead to further changes in the volume of spill needed for fish passage, which could further reduce the Project's effect on TDG levels. Chelan PUD will continue to study and refine the juvenile bypass system's effectiveness with the goal to reduce or eliminate the need to spill to meet fish survival objectives.

Figure 9: Improvement in TDG Management from 2000 to 2003, Despite Increased Spill in 2003 to Meet HCP Survival Goals



2.4.2.4 <u>Near-Field Effects Study</u>

A study of near-field effects of specific spillgate and powerhouse operations on TDG levels was conducted in 2002 (Total Dissolved Gas Exchange During Spillway Operations at Rocky Reach Dam, April 26-May 3, 2002; COE, 2003) to improve the understanding of how different gate settings affect the level of TDG produced for specific volumes of spill. Near-field refers to the close proximity of the TDG measurements to the Project structures, in contrast to fixed-monitoring stations that are located some distance downstream of the tailrace. The near-field effects study avoids the compounding effects of TDG levels in the water arriving at the Project and variability associated with mixing spill and powerhouse flow under different flow volumes. The study included a number of TDG monitoring devices placed in both mixed and unmixed zones below the Project (Figure 10).

Figure 10: Near-field TDG Sampling Stations at Rocky Reach Dam (COE, 2002)

A number of different spillgate configurations were tested to determine how best to manage spill operations to limit TDG levels. The spillway flow ranged from 10.6-61.0 kcfs during the study. In addition, two different modes of powerhouse loading were tested by concentrating discharge through either the south or north end of the powerhouse. The normal (standard) spill pattern uses a variable number of spillgates, three spillgates (4, 6 and 8) for total spill volumes below 20,000 cfs, increasing the number of gates as needed up to 7 spillgates (2 through 8) for spill volumes above 50,000 cfs. The standard spill pattern was developed to create tailwater conditions generally conducive to adult salmon passage (a V-shaped margin of aerated water leading to adult fishway entrances). Discharge through individual spillgates ranged from about 4,000 to 10,000 cfs for total spillway flows of about 10 to 60 kcfs, but discharge was not evenly distributed through the spillgates. Alternative spillgate configurations included spreading spill evenly over seven spillgates, evenly over 11 spillgates, and concentrating spill into three different locations on the spillway (2 to 5, 5 to 8 and 9 to 12).

The study concluded that spillway operations at the Rocky Reach Hydroelectric Project increased average TDG level in the Columbia River between the spillway by 1.8 to 8.6% over levels arriving at the Project. However, this study was conducted when the TDG level in the forebay was below 110%, which is rarely the case during the fish migration season. As discussed previously, the increase in TDG level at the DFMS ranged from 0 to 3.5% TDG during spring spill in 2004. Thus the increase in TDG level was greater than occurs during the fish migration season and no degassing effect could be studied.

The standard spill pattern and a uniform pattern using gates 2 through 12 had the lowest TDG of the spillgate configurations tested. The uniform spill pattern (gates 2 through 12) produced slightly less TDG than the standard pattern for total spill levels of about 50,000 cfs. However, the powerhouse discharge was significantly higher during tests under the standard spill pattern, and mixing of powerhouse flow may have prevented observation of a greater difference between these spillgate configurations at the lower spill levels.

The entrainment of powerhouse flows, mixing with spillway discharge, influenced TDG levels. Increases in powerhouse discharge while spill discharge was held constant resulted in a decrease in the maximum TDG level, which is likely due to mixing of powerhouse flow with the spillway flow. Although the mixing effect reduces the maximum TDG level measured, the entrainment of powerhouse flows into the highly aerated spill discharge results in a greater total volume of flow having elevated TDG levels. Powerhouse flow entrainment resulted in an increase of 1.1% in the average TDG level at sampling transect LD, which was located downstream of transect FO in Figure 10. TDG transfer from spilled water to powerhouse discharge flows could be minimized by spilling at bays farther from the powerhouse (by using bays 2 through 12) and by maintaining a downstream powerhouse priority for unit operations. During the fish migration season, the downstream powerhouse priority for unit operations is already in effect as a measure to guide fish to the juvenile bypass system.

The relationship between total spill discharge and TDG at the end of the aerated zone (transect SB) for each spill pattern was linear at the spill levels tested (Figure 11). The linear regression line for the standard spill pattern intercepts a TDG level of 120% at a spill discharge of 56,000 cfs. Assuming a hydraulic capacity of the powerhouse at Rocky Reach Dam of 204,000 cfs, the spillway discharge during the 7Q10 flow using the standard spill pattern would be less than a TDG level of 120% based on these findings. Since TDG continues to decline below the aerated zone, the TDG level at the DMFS is lower than 120% at this spill level.

In addition to the analysis of different spill patterns, the study evaluated whether the existing fixed monitoring sites (forebay and DMFS) accurately represents the TDG levels in the river. The forebay monitoring site did represent TDG levels in the Columbia River arriving at the Project. The DMFS was found to underestimate the average TDG level across the river channel at that location by about 1%. Transects conducted during yearly monitoring find the DMFS is typically within 1% to 2% of the highest TDG level across this transect location.

The COE compared the TDG exchange (gas sorbing into and out of water) of the Rocky Reach spillway to other Columbia River hydroelectric projects. They concluded that TDG exchange at the Rocky Reach Hydroelectric Project dam is similar to TDG exchange at Lower Granite Hydroelectric Project dam, which has been equipped with gas abatement technology (spill flow deflectors). At Lower Granite Dam during the 2002 spill season, the TDG level in spillway releases reached 115% for a spill discharge of about 32,000 cfs (38% of a 7Q10 flow (84,000 cfs) if the powerhouse is running at full capacity), and 120% for a spillway discharge of about 53,000 cfs (63% of a 7Q10 flow if the powerhouse is running at full capacity). The TDG response for a comparable spill discharge at Rocky Reach Dam was similar to conditions observed at Lower Granite Dam after installation of spillway flow deflectors. The TDG level at Rocky Reach, using the standard spill pattern, reached 120% in the tailrace, at a spillway discharge of 62,700 cfs (131% of a 7Q10 flow if the powerhouse is running at full capacity, or 96% if a small turbine is down; Figure 11). However, the Lower Granite Dam powerhouse hydraulic capacity is much lower in relationship to the 7Q10 flow for the Snake River, thus during high flow years the spill level at Lower Granite Dam will cause much higher TDG levels than will occur at Rocky Reach Dam in high flow years.

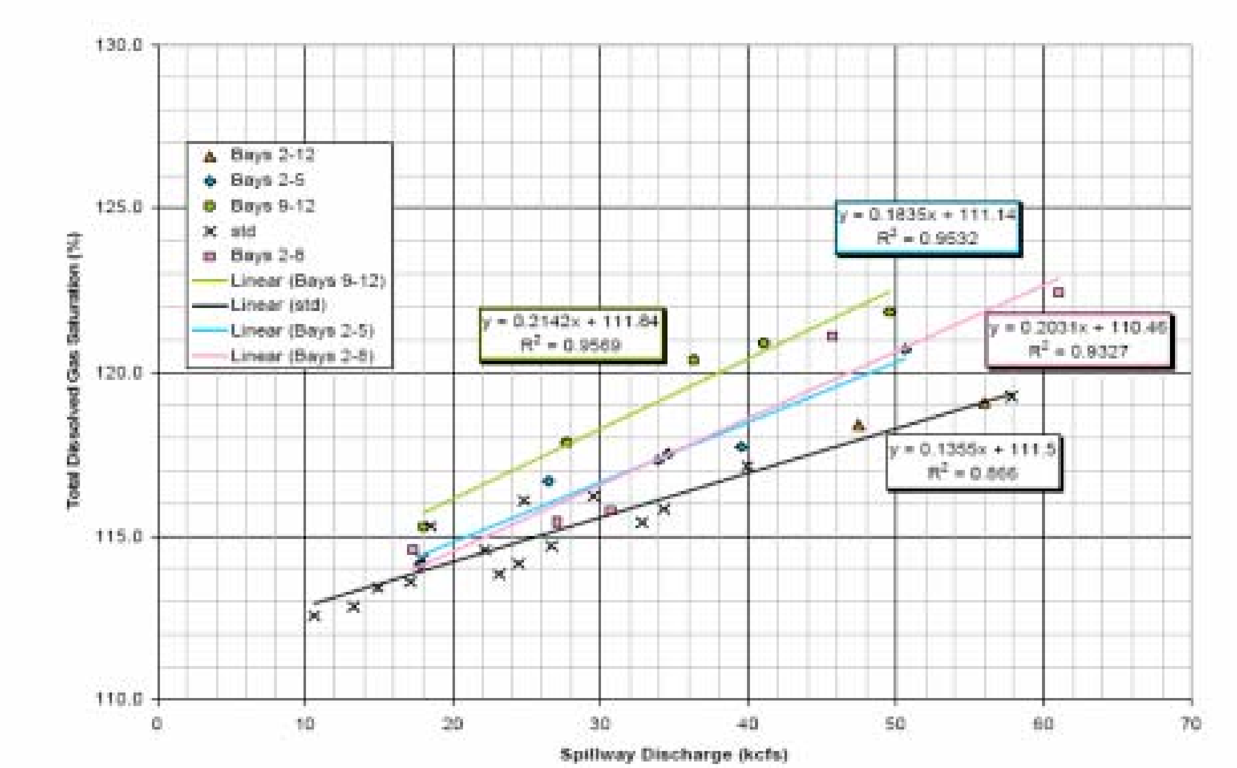


Figure 11: Maximum TDG in the Tailrace as a Function of Total Spill Flow, April 26 – May 3, 2002

At many federal projects on the Columbia River, a predictive model, SYSTDG, is one of the tools used to manage spill and prevent exceedances. The standard spill pattern TDG regression was tested with the SYSTDG model to evaluate its applicability to spill management at the Rocky Reach Project. SYSTDG predicted the TDG exchange at Rocky Reach Dam as a function of the forebay, background TDG level and Rocky Reach project operations. High forebay TDG pressures reduce the allowable spillway discharge to avoid leading to excessive TDG at the fixed monitoring sites downstream of the dam. A review of historic records of TDG levels indicated that the 115% criterion for the forebay of Rock Island Dam, rather than the 120% criterion for the tailrace monitoring station, will be the location where exceedances are most likely to occur. This is particularly true when the TDG level arriving at the Rocky Reach forebay is high. The predictive error of the SYSTDG model was within a TDG level 0.3% over 90% of the study period (April 26-May 3, 2002). The SYSTDG model could be used as an additional tool to manage spill and prevent exceedances downstream from the Project.

2.5 Water Temperature

2.5.1 Water Quality Standard for Water Temperature

The 1997 Class A water quality standards for water temperature applicable to the Columbia River at the Project include both narrative requirements and numerical criteria. Those water quality standards most pertinent to the Project, and relevant to the daily maximum temperature, are:

- Temperature shall not exceed 18.0°C due to human activities.
- When natural conditions exceed 18.0°C, no temperature increases will be allowed which will raise the receiving water temperature by greater than 0.3°C. When temperature is below 18.0°C, the incremental temperature increase described below governs.
- "Natural conditions" or "natural background levels" means surface water quality that was present before any human-caused pollution.
- Incremental temperature increases resulting from point source activities shall not, at any time, exceed $t=28/(T+7)$. For purposes hereof, “t” represents the maximum permissible temperature increase measured at a mixing zone boundary; and “T” represents the background temperature as measured at a point or points unaffected by the discharge and representative of the highest ambient water temperature in the vicinity of the discharge.
- Incremental temperature increases resulting from nonpoint source activities shall not exceed 2.8°C.

2.5.2 Water Temperatures Measured in Project Waters

The temperature of water flowing into and through the Rocky Reach Hydroelectric Project reservoir typically begins warming in March, reaches peak annual temperatures in late July through early September (monthly average daily temperature for August at the forebay is 17.7°C) then cools again during the fall and winter months to average temperatures in the 3°C to 4°C range (Figure 12). Daily variability is typically less than 0.5°C but can range as much as 1°C diurnally during summer. The reservoir is not known to stratify (Chelan PUD, 1991; Johnstone and Mih, 1987). The forebay monitoring site, which is the same as the TDG forebay fixed monitoring site, measures water temperatures at the face of the dam at a depth of about 15 feet. The total depth at this location is 120 feet (36.5 meters).

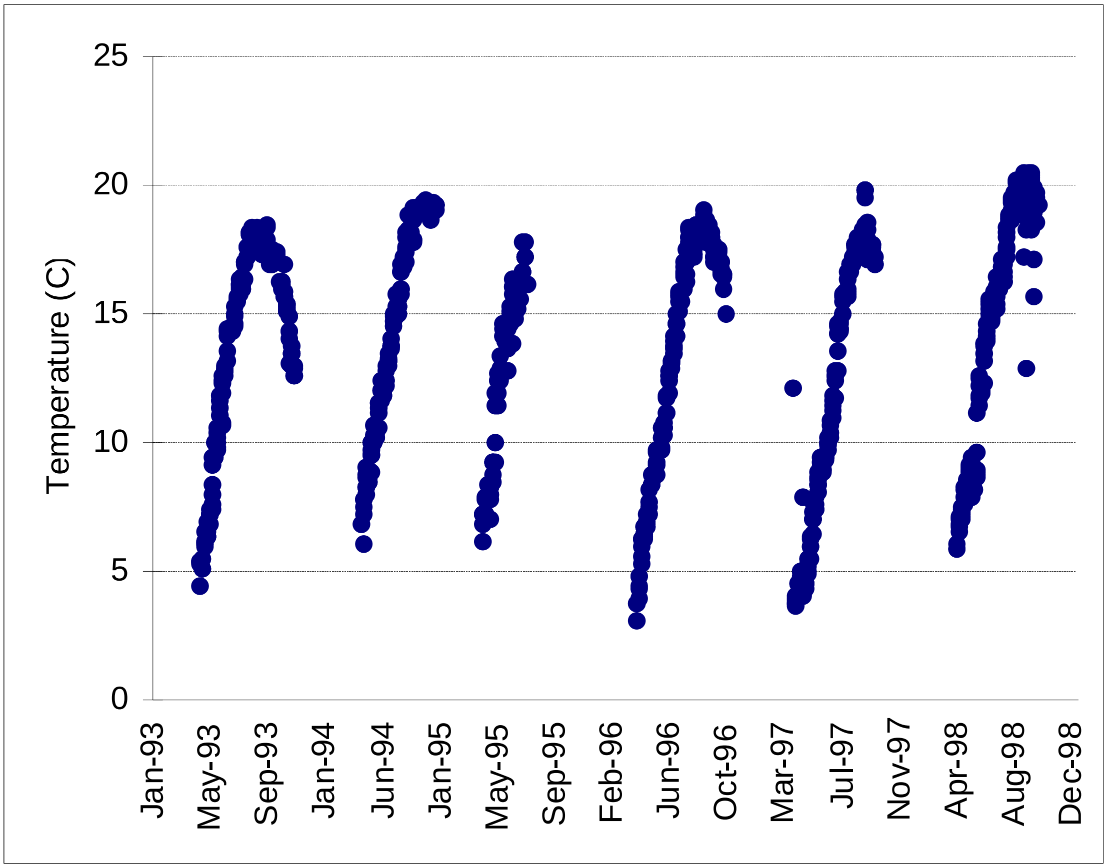


Figure 12: Daily Water Temperatures at Rocky Reach Hydroelectric Project Forebay 1993-1998 (PDEA)

Chelan PUD funded a detailed study of water temperatures in the Rocky Reach Reservoir in a drought year, 2001 (Parametrix and TRPA, 2002). Under the low flow conditions prevalent in this year, water temperatures exceeded 18.0°C for most of the period from late August through September (Figure 13).

Agency stakeholders had expressed an interest in better defining temperature gradients longitudinally, transversely, and vertically. Temperature profiles were measured at three-meter depth intervals across eight transects in the middle and lower reservoir. The lateral, (cross-channel) temperature profiles (transects) were collected on September 1 and 2, 2001. At each site, transect data were collected in the morning and again in the afternoon. Transects were run from the west bank to the east bank of the reservoir. Ten or eleven monitoring stations were distributed across each transect at approximately equal spacing, with the end stations placed within one meter of shore. The maximum depth measured at deeper stations, which corresponded to the maximum depth of the river at each location, was approximately 35 to 40 meters (115 to 131 feet).

The lateral temperature data indicated that the mainstem flow of the river is very well mixed with regard to temperature. The warmest temperatures were observed in shallower water at either end of the transects, and in near-surface waters measured during the afternoon. Temperature differences between the near-surface readings and bottom readings at most stations ranged between -0.1 and 0.3°C in the morning, and between 0.0 and 1.1°C in the afternoon. This pattern indicated afternoon warming of the near-surface waters. The daily heating effect of solar radiation was demonstrated by the differences between maximum and minimum temperatures for each transect. For most transects these differences between the highest and lowest temperature observed throughout a given transect (not within one station, but across the transect stations) ranged between 0.2 and 0.6°C in the morning and from 0.8 to 2.1° C in the afternoon.

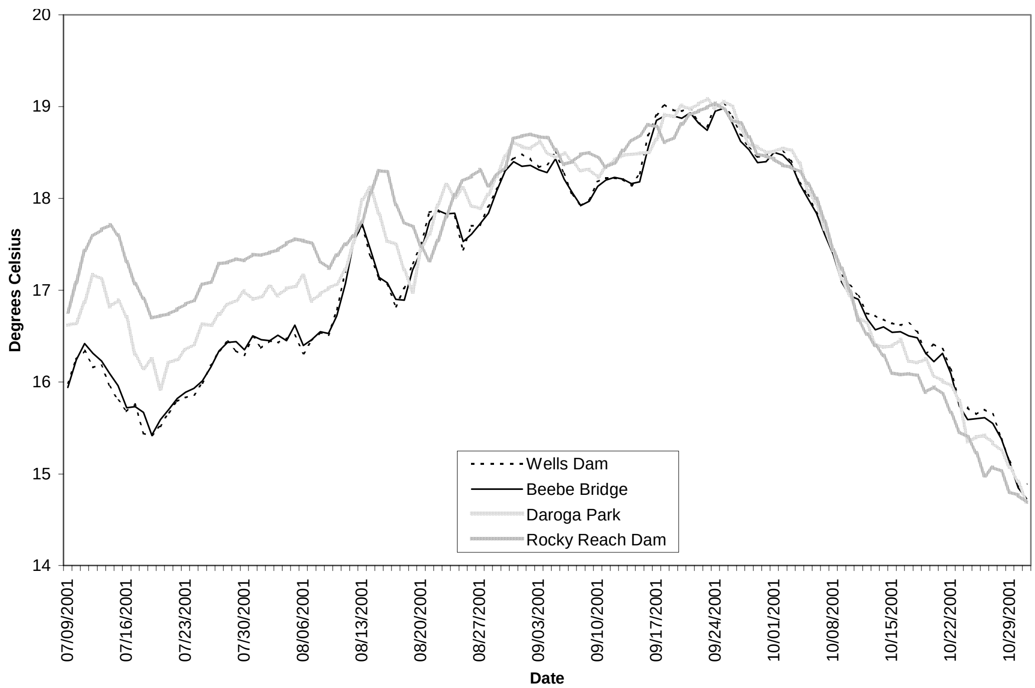


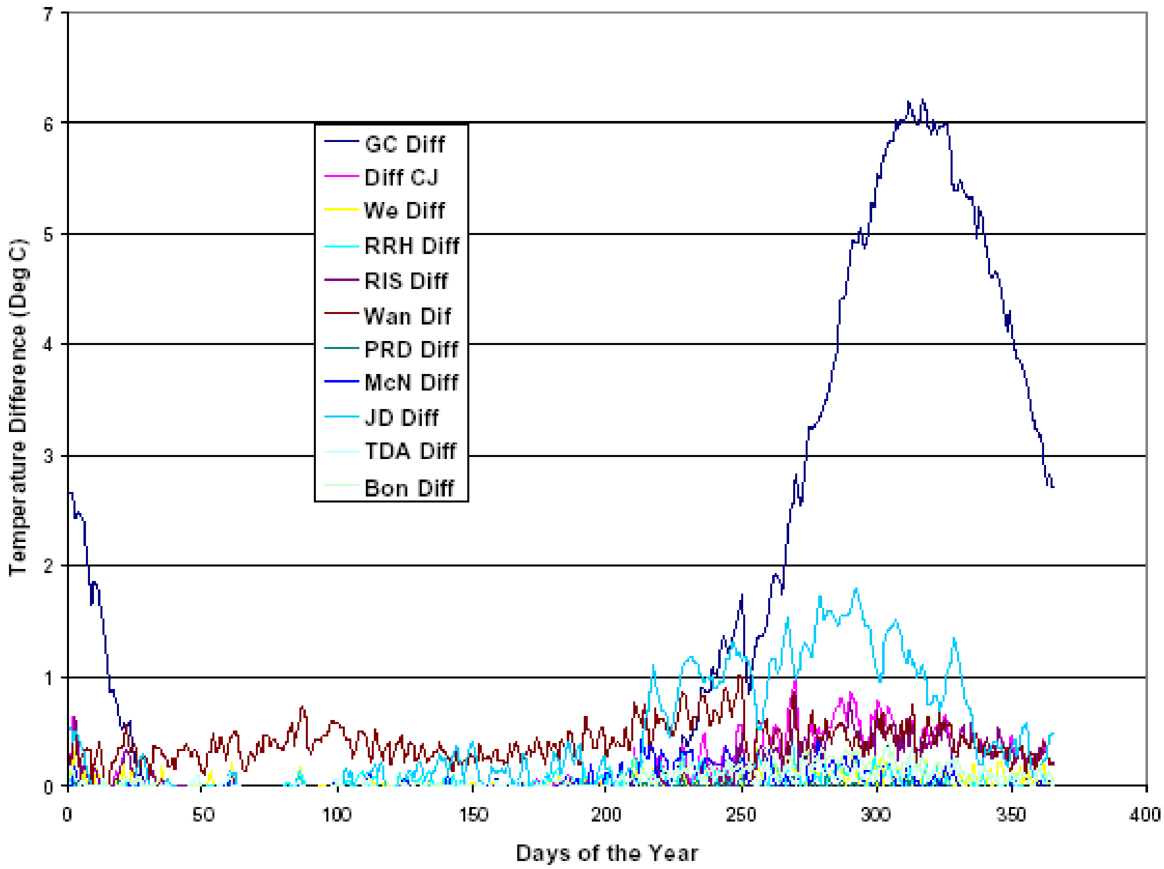
Figure 13: Water Temperatures Observed in the Rocky Reach Reservoir in 2001(Parametrix and TRPA, 2002)

2.5.3 Project Effect on Water Temperatures Estimated from Model Studies

The effect of the Rocky Reach Project on water temperatures has been evaluated by four different model studies. All these model studies have demonstrated that the Project has a small effect on water temperature, but that most of the factors affecting Columbia River water temperatures are outside the control of the Project. For example, the existence of major storage projects above the Project have changed both the water temperatures arriving at the Project and the volume of Columbia River flows passing through the Project. These are major factors that influence the thermal effect of the Project and define the limitations that any measures taken at the Project would have on the water temperature in the Columbia River. Historically, the Columbia River exceeded the 18.0°C temperature criterion under natural conditions in the Rocky Reach Hydroelectric Project area. Data from the Rock Island Hydroelectric Project demonstrate frequent exceedances of 18.0°C prior to construction of any other hydroelectric project dams upstream. Studies by Sylvester (1957), Davidson (1969) and EPA, as summarized by Parametrix and Rensell Associates (2001), have all shown that the Columbia River typically exceeded 18.0°C during the month of August. However, the temperature regime changed following construction of Grand Coulee Hydroelectric Project dam and other large storage reservoirs in the upper Columbia River. This altered river environment is the background condition for any practical consideration of water temperature management plans and the effect of the Rocky Reach Project must be considered in the context of the developed Columbia River Basin.

2.5.3.1 EPA Temperature TMDL Model Analysis with RB10 (One-Dimensional Model)

EPA water temperature modeling, using a one-dimensional model and 30 years of data (RB10 model, Yearsley, 1999), indicated that generally the Columbia River increases in temperature through spring and summer at about the same rate as before construction of the hydroelectric projects. However, the river without reservoirs had much lower flow rates in late summer and water temperature was much more variable in response to changes in climatic conditions. Peak temperatures during hot weather were often higher than today, but on average the river exceeded 18.0°C for a shorter duration before the hydroelectric project dams were constructed (EPA, 2001). EPA has issued a review draft TMDL for temperature on the Columbia River. Supporting data presented by EPA at public workshops and in the draft TMDL's appendices show that most of the temperature changes due to human effects are the result of large storage reservoirs. Smaller run-of-river projects, including Rocky Reach Hydroelectric Project, have much less of an effect on water temperatures. The results of comparing the 30-year average temperature shows that the individual temperature effects of Rocky Reach and other small run-of-river projects is quite small compared to the projects with larger reservoirs (Figure 14). The EPA modeling results also show that Rocky Reach Reservoir, when compared to a theoretical river segment with the reservoir removed and all upstream dams removed, has the tendency to increase the cooling of water temperatures from October-June, and increase the heating of water from July-September (Figure 15). As seen in Figure 15, the Project's effect on water temperature, averaged over 30 years and assuming that Wells and Chief Joseph dams were removed, is generally less than 0.2°C. As demonstrated by the jagged appearance of the line in Figure 15, the RB10 model's precision is insufficient to predict if the Rocky Reach reservoir's effects on water temperature are always within 0.3°C of water temperatures that would occur if the Project did not exist. The RB10 model does have sufficient precision to predict trends and long-term averages, thus the prediction that the Rocky Reach Project would, on average, have less than a 0.2°C effect of increasing local water temperatures if there were no dams below Grand Coulee Dam is a valid prediction.



(Acronyms for individual dams are GC (Grand Coulee), CJ (Chief Joseph), We (Wells), RRH (Rocky Reach), RIS (Rock Island), Wan (Wanapum), PRD (Priest Rapids), McN (McNary), JD (John Day), TDA (The Dalles) and Bon (Bonneville). Rocky Reach is represented by the light blue line close to the X-axis.**)**

Figure 14: Effects of Individual Hydroelectric Project Dams on Daily Cross-Sectional Average Temperature in the Columbia River (EPA, 2000)

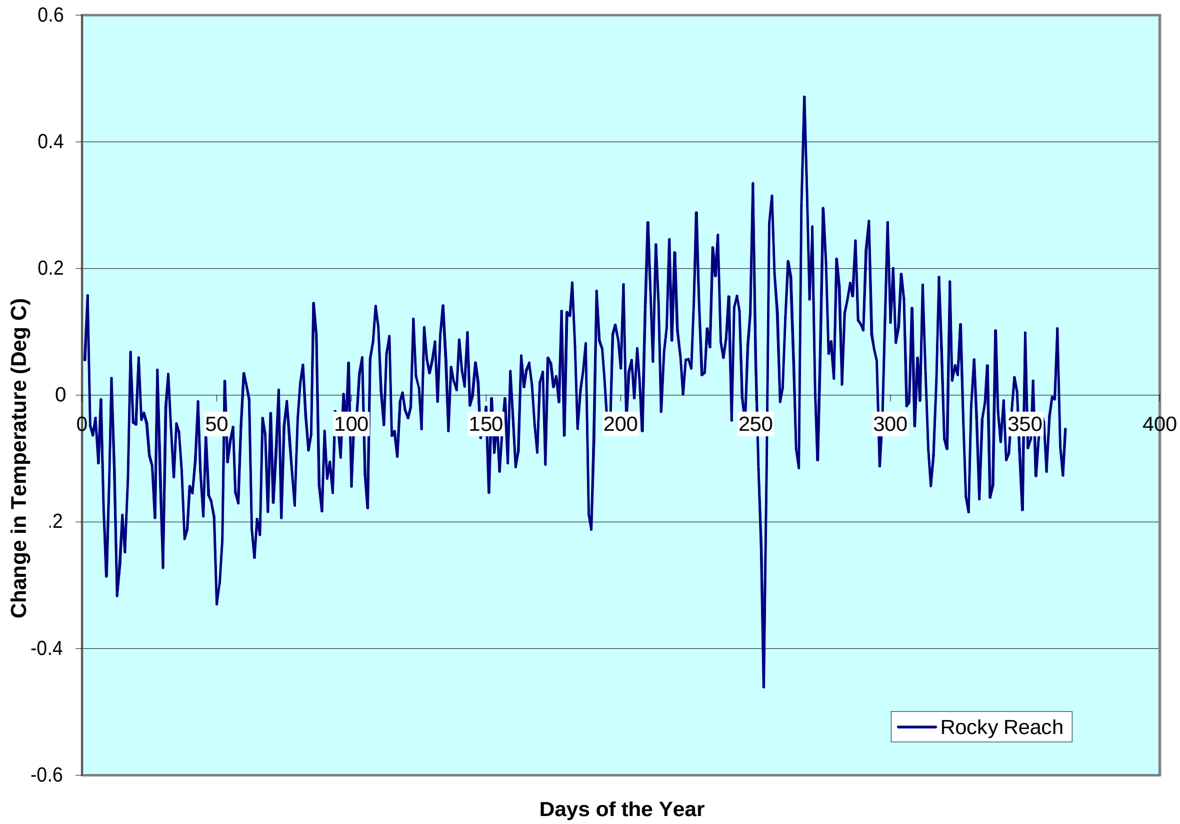


Figure 15: Estimated Effect of Rocky Reach Reservoir on Water Temperature, Using EPA RB10 Model and a 30-Year Period (EPA, 2000)

In a later analysis, EPA estimated the effect of the Rocky Reach Reservoir on the current Columbia River condition, with Wells Dam and the other upstream projects still in place (Figure 16). The effect of the Rocky Reach Project on water temperatures in this situation is much less, since water temperatures arriving at the site have already been buffered from daily climatic conditions by the upstream projects (primarily influenced by Grand Coulee Project). In general, the continued existence of the Rocky Reach Project would tend to keep the daily maximum water temperature cooler, if averaged for the entire year, by preventing the warming that would occur if the reservoir were removed (Figure 16). The greatest warming effect, from July to mid-August, would typically be less than 0.1°C change in the daily average temperature with the reservoir in place. The existence of the Rocky Reach Reservoir has a cooling effect on the impounded river system after mid August. The EPA analysis also examined the downstream, or cumulative effect, of the Rocky Reach Project on temperatures in the McNary reservoir under the impounded river condition (Figure 17). The cumulative heating effect was less than 0.05°C in summer, with a beneficial cooling effect reaching 0.1°C by mid-October when Chinook salmon begin spawning in the Columbia River.

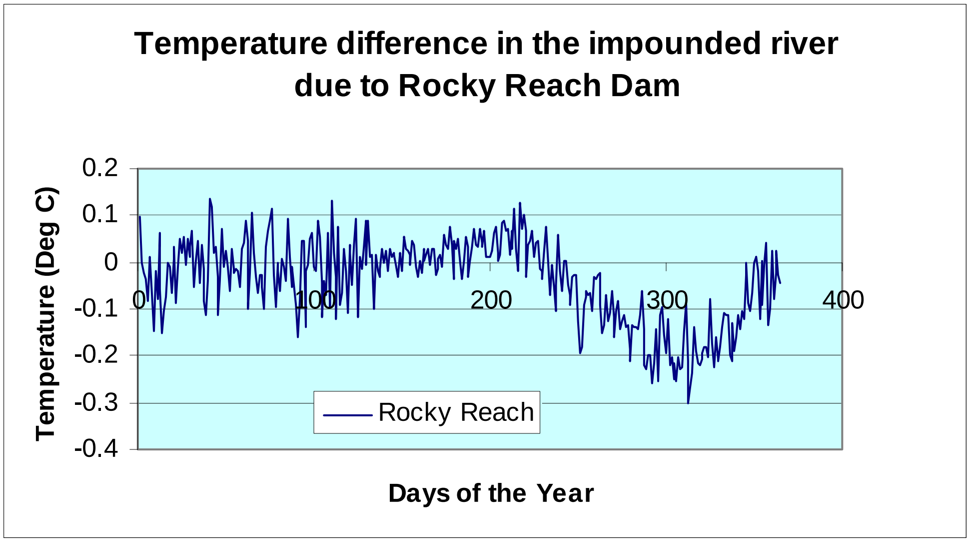


Figure 16: EPA Model's Estimated Local Temperature Effect of Rocky Reach Project in the Impounded Columbia River (EPA, 2000)

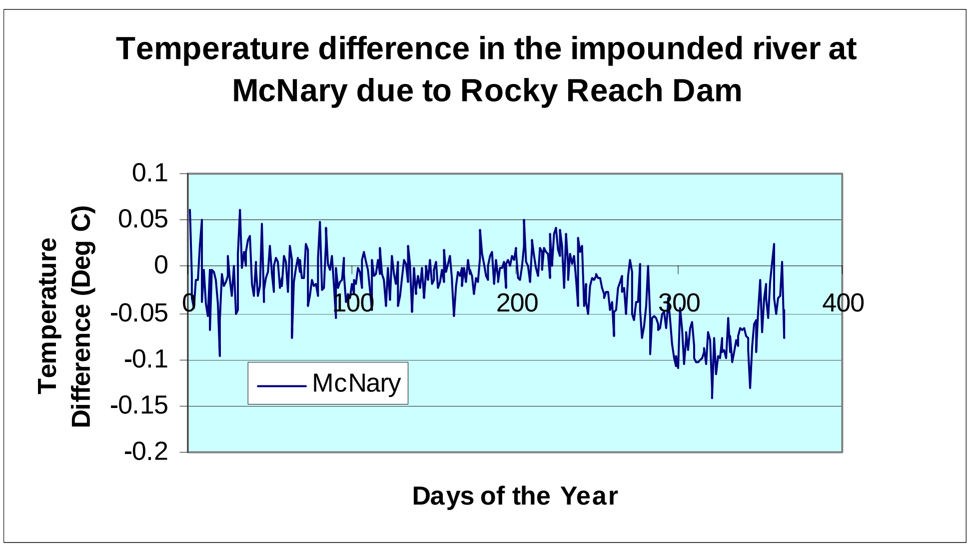


Figure 17: EPA Model's Estimated Downstream Effect of Rocky Reach Project in the Impounded Columbia River (EPA, 2000)

2.5.3.2 Model Study Using SNTEMP for 2000 and 2001 (One-Dimensional Model)

Parametrix and TRPA (2002) estimated the effect of the Rocky Reach Hydroelectric Project reservoir on water temperature during the 2001 drought year, using the Stream Network Temperature Model (SNTEMP). Data available prior to model selection and for 2000, which was for years with normal summer flows, indicated little vertical or lateral stratification of the reservoir (which supported the use of SNTEMP). However, 2001 was a year of extreme low summer flows and significant longitudinal stratification, a difference in temperature from upstream to downstream, was observed in the data. A problem encountered in applying SNTEMP to the Rocky Reach Hydroelectric Project was related to model reliance on daily time steps with no “carry-over” of heat transport across days. During the low flows in 2001, the daily time step did not adequately represent the transfer of water through the reservoir. For low flow years, such as 2001, different models such as CE-QUAL-W2, MASS 1 or MASS 2 (Modular Aquatic Simulation System 1D and 2D) were determined to be better predictors of quantitative temperature changes as a result of the project.

To compensate for the low flows in 2001, the SNTEMP model was adapted to these conditions by treating the Rocky Reach Reservoir as three separate stream segments. In the process of calibrating the SNTEMP model, the simulated temperatures under the measured climatological and hydrological conditions in 2001 were as expected for the upper reservoir (Beebe Bridge), but time lags of one day at mid reservoir (Daroga Park) and two days at Rocky Reach Dam were observed. To determine the cause of this time lag, Chelan PUD applied the FloodWav model to Rocky Reach Reservoir in 2001 to determine water travel times. FloodWav, maintained by the National Weather Service, computes water travel times in a depth and width-averaged manner (i.e., one-dimensional, plus-time scale), and predicted travel time from Wells Dam under the average 2001 study period flow of 60,000 cfs (extreme drought conditions). The predicted water travel times from Wells Dam were 0.44 days to Beebe Bridge, 1.56 days to Daroga Park, and 3.51 days to Rocky Reach Dam. This simulated delay in water movement within the reservoir generally matched the downstream temperature data recorded by the installed thermographs.

This water travel time information was used to modify the study by segmenting the reservoir into three sections. This effort partially compensated for the one-dimensional limitations of the SNTEMP model. However, even though the reservoir was segmented into three sub-reach SNTEMP models (and starting temperatures for each sub-reach used observed temperatures at their upstream boundaries), the delayed transport of warmed (or cooled) water from upstream still prevented accurate temperature simulation that would correspond to the observed temperatures on a daily basis. An additional factor may have been the increasing water volume closer to the dam (in relation to total flow) that retains heat energy with less potential for water surface/atmospheric interchange. Still, some conclusions can be drawn from the SNTEMP model study that support and expand on information developed with EPA’s RB10 model.

To assess the warming or cooling effect of the Rocky Reach Reservoir on Columbia River temperatures, a pre-dam alternative was simulated by modifying the previously calibrated SNTEMP model. Water surface elevations, channel widths, and topographic shade were the key structural data changed within the model to allow for a simulation under ‘natural’ conditions. The pre-dam alternative was used to simulate stream temperatures within the three study reaches using 2001 and 2000 meteorological and hydrologic data. At Beebe Bridge, in both 2001 and 2000, the dam exhibited minimal influence on water temperatures. Under 2001 conditions (drought), at Daroga Park, there is more evidence that the reservoir was having a warming effect earlier in the season. This effect held until late September when simulated without-dam temperatures were warmer than with-dam temperatures. This same relationship held true under 2000 conditions (normal flow year), but the crossover occurred earlier, in early August. At the

Rocky Reach Dam (lower reservoir sub-reach) the same relationships held true in both years, except the magnitude of the temperature differences was amplified.

In the broadest sense, Rocky Reach Reservoir appears to influence some warming of the river during July and early August and some cooling during later August, September, and October. This seasonal effect is most apparent downstream in the reservoir near the dam, and both the magnitude and timing of the effect is influenced by river flow. However, accurate quantification of the effect is limited with the SNTEMP model.

The SNTEMP model was sufficiently accurate to make general predictions about the relative effect of the Project on water temperatures under different flows and climatic conditions. Figure 18 and Figure 19 show the simulated effect of the Project on water temperatures under the actual climate and flow conditions experienced in 2000 and 2001. The flows used in the without-dam simulation were not “natural” flows; rather the flow was augmented during the summer as set by the FCRPS Biological Opinion and power demand. Temperature differentials between the with-dam and simulated without-dam alternatives were lower during 2000 than during the drought year of 2001. Maximum temperature warming effect of the Project would occur during a combination of low river flow, high air temperature, and greatest day length. Maximum temperature cooling attributable to the project would also occur during low river flow, but with a low air temperature and shorter day length. Because 2001 was a year of extreme drought, conditions on two days in 2001 were representative of maximum heating and cooling effect of the Project. The SNTEMP model predicted about a 0.5°C increase in water temperature on July 12, 2001, when flow was 40,000 cfs and air temperature was 27°C and day length was long. A temperature decrease of 0.4°C was predicted for October 27, 2001, when flow and air temperature were also low and day length shorter. These predicted temperature effects for extreme conditions are reasonable in comparison to the predictions made with the EPA RB10 model (0.2°C average Project effect over 30 years).

There were several important trends to note from the SNTEMP study (Figure 18 and Figure 19). There was very little daily effect on water temperatures in 2000, whereas temperatures in 2001 were more affected in July before the river reached peak temperatures. The Project had no consistent effect on the peak temperatures in August and September of 2001; sometimes the without-dam simulations had higher temperatures than the with-dam simulation. The Project contributed to accelerated cooling of water in early October, when Chinook salmon begin mainstem spawning in the Rocky Reach Reservoir and the Hanford Reach of the Columbia River. This finding was also consistent with the EPA RB10 model. Total flow volume in the Columbia River appears to be the principal factor determining the magnitude of the effect of Rocky Reach Dam on water temperature. The greatest Project effect, whether heating or cooling, occurs during low flows.

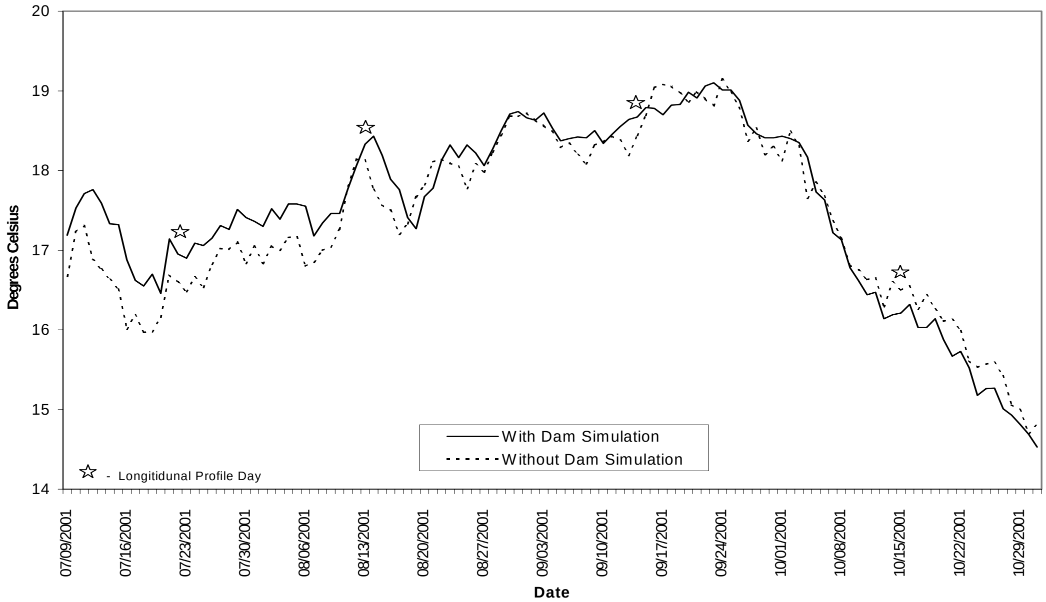


Figure 18: Daily Average Summer Water Temperature Simulations at the Location of Rocky Reach Dam, With and Without the Project, for the Low Flow Drought Year 2001

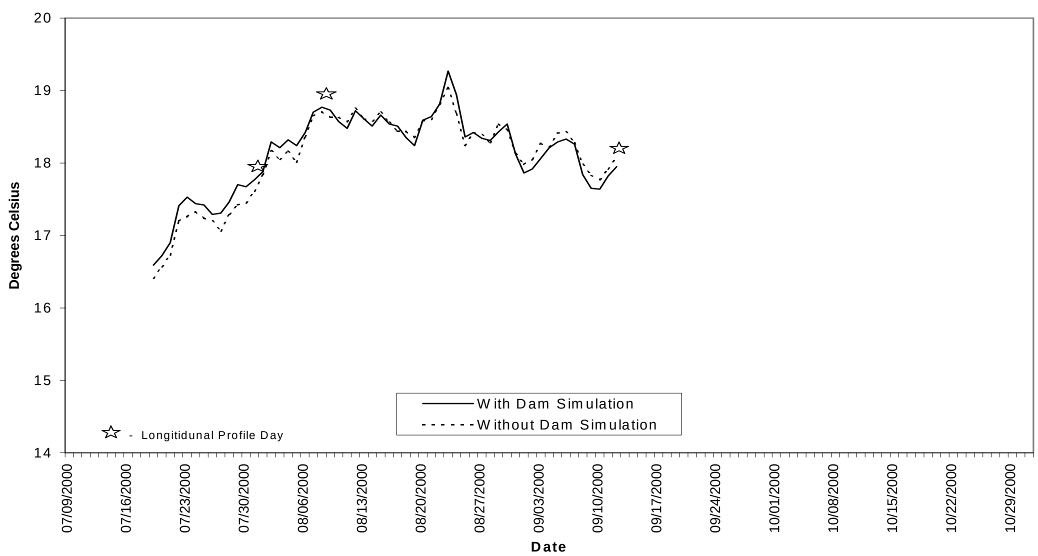


Figure 19: Daily Average Summer Water Temperature Simulations at the Location of Rocky Reach Dam, With and Without the Project, for the Average Flow Year 2000

2.5.3.3 Model Analysis Using CE-QUAL-W2 (Two-Dimensional Model)

The water temperature model chosen to provide a two-dimensional (longitudinal-vertical) model of the RR reservoir was a public-domain model, CE-QUAL-W2 Version 3.2, which is widely used to measure the effects of reservoirs on water temperatures and is being used to evaluate water temperature effects and mitigative actions in other parts of the Columbia River Basin. CE-QUAL-W2 is a water quality and hydrodynamic model for rivers, estuaries, lakes, reservoirs and river basin systems. This model has an automatic timestep, so it calculates the maximum allowable timestep and self-adjusts to ensure that hydrodynamic stability requirements are not violated. This feature makes the model equally robust across a large variety of flow regimes, compensating for the shortcomings of SNTEMP.

WEST Consulting, Incorporated (WEST) was selected to prepare the model of the Project. The modeling and review process was funded by Chelan PUD, and conducted in collaboration with WDOE, a peer review group of water temperature modeling experts, including the developers of the model, and a subcommittee of stakeholders in the relicensing settlement process, the Water Quality Technical Group.

Input data for the CE-QUAL-W2 model of the Project included bathymetry, flows, inflow water temperatures, meteorology, and in-pool temperatures for model calibration (WEST, 2005). Initially, Chelan PUD selected the summers of 2000 and 2001 for the CE-QUAL-W2 model calibration and simulation periods based on available data collected during water quality studies done in these years. WEST collected input model data for all of 2000 and 2001 to ensure that sufficient time was included in the model to ensure that the initial conditions were not affecting results. The model calculated a residence time of approximately two days assuming a level pool elevation between 703 and 707.

Once the model was developed and calibrated it was subjected to rigorous review by the peer review panel described above. When it was determined to be acceptable, two entire years of hourly, or equivalent, empirical climatic and flow data from 2000 and 2001 were input and water temperatures simulated for with and without Project conditions.

At the conclusion of the simulation of years 2000 and 2001, the Water Quality Technical Group determined that it was important to model more than two years, and that years that represent very low flow or very warm climate (worst case) should be represented in the years modeled in order to conservatively define the Project impact. Comprehensive, empirical, hourly climatic and flow input data are available for the years of 2000 through 2004. The climatic data were evaluated for each of these years to determine if low probability, worst-case years were present during this time period. It was determined that these five years include low probability, worst case conditions (Chelan PUD, 2005). Specifically, the average summer (June through August) ambient air temperatures of 2003 and 2004 were very warm years with only a 6% probability that a year would have a warmer summer. The Water Quality Technical Group decided that 2002 through 2004 should be modeled to determine if the Project exceeded water quality standards during those years and that the findings would conservatively describe the overall Project impact.

WDOE has chosen to use the existing water temperature and flow regimes entering the Project's boundary as the background condition for the 401 Certification analyses to determine whether the Project's reservoir increases daily maximum water temperatures above the allowable incremental increase.

The simulated with-Project results were compared to the observed data for each year. The absolute mean error of the with-Project simulation was calculated and is presented in Table 3.

Table 3: Absolute mean error simulated with-Project temperatures

Location	Absolute Mean Error (°C)				
	2000	2001	2002	2003	2004
Rocky Reach Forebay	0.2	0.2	0.2	0.2	0.3
Rocky Reach Tailrace	0.1	0.1	0.1	0.1	0.1

The CE-QUAL-W2 model was used to simulate the without-Project condition, but empirical data does not exist for calibration of the without-Project model. To provide assurance that the CE-QUAL-W2 model provided an unbiased estimate of the without-Project condition, the CE-QUAL-W2 simulated model output was compared to output from simulations performed using a different model with an independent approach for simulating the without-Project hydrologic conditions. The Modular Aquatic Simulation System 1 model (MASS1), a one-dimensional hydrodynamic and water quality model (Battelle, 2005), was chosen for this comparison. MASS1 has previously been applied to the middle Columbia River to simulate temperature for both impounded and free-flowing conditions, and calculates water surface elevation, discharge, and water temperature as a single cross sectional average value at each computational point in the system. Simulations of Columbia River temperatures with MASS1 have been used to simulate the free-flowing conditions in the Hanford Reach where empirical data for calibration does exist, and to simulate conditions downstream of Rock Island Dam prior to construction of the Priest Rapids Project.

The comparison of the CE-QUAL-W2 and MASS1 models match within 0.2°C for the impounded scenario (Figure 20) and within 0.1°C for the without-project scenario (Figure 21). The slightly larger errors for the impounded scenario are expected and are due the weak stratification in the reservoir, which is not captured by the one-dimensional MASS1. For the without-project scenario when the river is not stratified, the two models generate almost identical water temperature solutions.

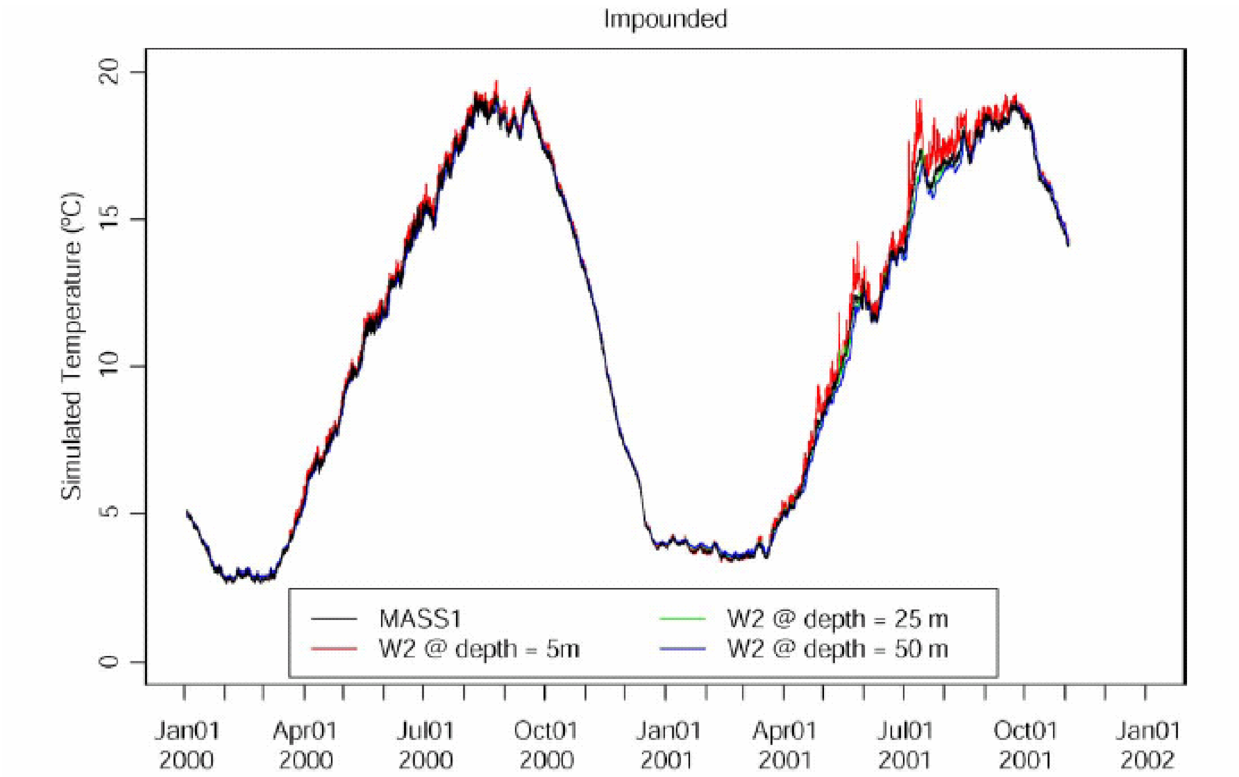


Figure 20: CE-QUAL-W2 versus MASS 1 with-Project simulations

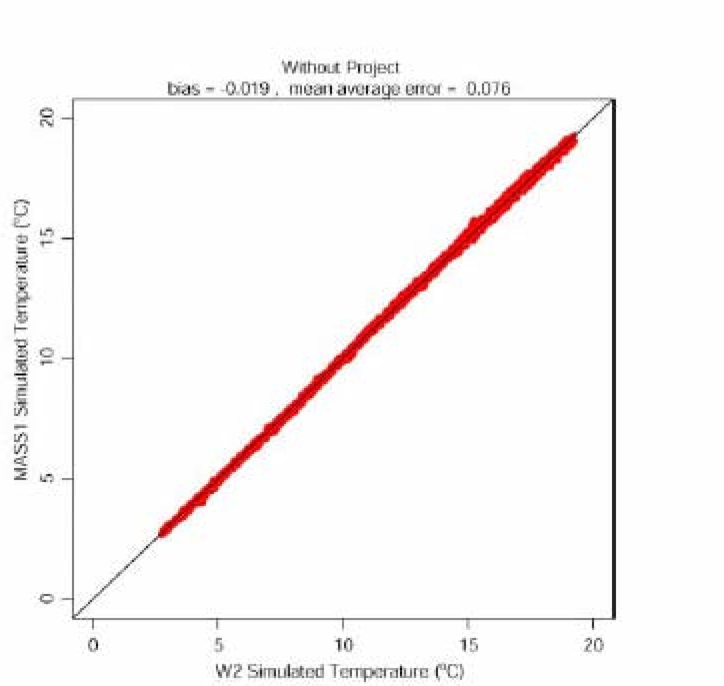


Figure 21: CE-QUAL-W2 versus MASS 1 without-Project simulation comparison

A comparison of the with and without Project daily maximum temperatures was made at each of three locations (Beebe Bridge, Daroga Park, in the forebay) and subjected to the acceptability criteria described in the 1997 water quality standards and proposed standards. As stated above, 1997 criteria Class A water quality criteria state that water temperature will not exceed 18°C due to human effects. When natural conditions exceed 18°C, no temperature increases due to human effects will be allowed which will raise the water temperature by more than 0.3°C. Additionally, incremental temperature increases from human effects in waters below 18°C will not exceed $t = 28 / (T + 7)$ where T is the background temperature, nor will they exceed 2.8°C.

The proposed water temperature criteria are similar to the 1997 criteria except that a seven day maximum daily average is used as the basis of comparison, rather than the daily maximum temperature and the base temperature is set at 17.5°C is used instead of 18°C.

To compare the water temperatures at the forebay under the with-Project scenario to the same location without the Project, daily maximum flow-weighted and volume-weighted averages were calculated from the hourly data. The resulting comparison of the simulated project impact to allowable increases is presented in Table 4.

The flow-weighted average more accurately depicts the temperature of the main body of flow moving through the Project.Low velocity shoreline areas, shallows, embayments and back eddys represent a small proportion of the daily flows passing through the Project, but are likely to be warmer than the main river channel. The volume-weighted average is biased, placing greater weight on these areas than they contribute to the actual mass transport of heat through the Project. For this reason, the discussion presented will focus on the findings of the flow-weighted values. The volume-weighted results are presented in Table 4, for comparison.

Three cross-sections were evaluated along the reservoir. These include the forebay of the Rocky Reach Dam, Daroga Park, and Beebe Bridge. The simulated temperature effect of the Project was below the acceptable increase (based on 1997 criteria) for all simulations (spanning from January 2000 through December 2004) at Beebe Bridge and Daroga Park. At the forebay, three to six days per year yielded simulated differences between with-and without-Project temperatures greater than the acceptable increase. Typically, the difference between the simulated Project effect and the acceptable increase was less than the accuracy of the temperature probe (±0.2°C) that was used to provide the observed data that was used to calibrate the model. At the forebay, the simulated difference was larger than the acceptable impact on 20 days between 2000 and 2004, but one of those events (December 13, 2003) appears to be an anomaly from ~~a model instability~~inaccurate input data rather than a real simulated value. For all but five of these occurrences, the simulated and allowable increases were within the probe accuracy; therefore they were not measurably different from allowable.

Table 4: Comparison of simulated project impact to allowable increases

		Comparison to 1997 Criteria					Comparison to Proposed
Location / Output Type		2000[a]	2001[a]	2002[a]	2003[a]	2004[a]	2000 through 2004[a]
Flow-weighted	Beebe Bridge	None	None	None	None	None	None
	Daroga Park	None	None	None	None	None	None
	Forebay	8/26/00 (0.7/0.3) 8/27/00 (0.4/0.3) 9/01/00 (0.4/0.3)	8/15/01 (0.6/0.3) 8/16/01 (0.8/0.5) 8/26/01 (0.4/0.3)	7/31/02 (0.4/0.3) 8/1/02 (0.4/0.3) 8/16/02 (0.5/0.3)	7/17/03 (0.5/0.3) 7/18/03 (0.5/0.3) 7/30/03 (0.5/0.3) 10/11/03 (0.4/0.3) 12/13/03 (2.5/1.9)	7/19/04 (0.4/0.3) 7/26/04 (0.4/0.3) 7/27/04 (0.6/0.3) 7/28/04 (0.4/0.3) 8/11/04 (0.4/0.3) 8/12/04 (0.5/0.3)	8/16/01 (0.4/0.3)
/Volume-weighted	Beebe Bridge	None	None	None	None	None	None
	Daroga Park	None	8/12/01 (0.4/0.3) 9/17/01 (0.4/0.3)	None	None	None	None
	Forebay	8/26/00 (0.7/0.3) 8/27/00 (0.4/0.3) 9/01/00 (0.5/0.3)	8/15/01 (0.7/0.3) 8/16/01 (0.8/0.5) 8/26/01 (0.5/0.3)	7/31/02 (0.4/0.3) 8/01/02 (0.4/0.3) 8/02/02 (0.4/0.3) 8/16/02 (0.5/0.3) 9/19/02 (0.4/0.3)	7/17/03 (0.5/0.3) 7/18/03 (0.5/0.3) 7/30/03 (0.6/0.3) 10/11/03 (0.4/0.3) 12/13/03 (2.5/1.9)	7/19/04 (0.4/0.3) 7/26/04 (0.4/0.3) 7/27/04 (0.7/0.3) 7/28/04 (0.5/0.3) 8/11/04 (0.5/0.3) 8/12/04 (0.4/0.3)	8/15/01 (0.4/0.3) 7/27/04 (0.4/0.3)

a) Values given are the date, followed by the model predicted increase and the allowable increase.

On three of the five days, the difference between the simulated difference and the acceptable increase was 0.3°C.On one day (August 26, 2000) the model simulated a difference of 0.7°C, which was 0.4°C above the allowable increase of 0.3°C. These few occurrences of simulated Project effects greater than 0.2°C above the allowable increase are unlikely to be true indicators of the Project failing to meet numeric criteria for two reasons. First, the known potential sources of error in the model include the temperature probe that provided the observed data (accuracy of ±0.2°C) and the combined effects of the model's predictive error. The with-Project simulation (error of 0.2-0.3°C at the forebay; West, 2005), and the without-Project simulation (unknown, but assumed to be the same as the with-Project error) have a combined predictive error that is greater then either model by itself. The instrument error is not independent of the with-Project error, however, the with-Project and without-Project error should be independent. The joint error of the with- and without-Project models is approximately 0.3-0.4°C. Based on these sources of error, it is unlikely, given the single occurrence, that 0.7°C is statistically different than 0.3°C in this instance. The second reason that these five occurrences probably are not statistically significant is because there was only one case where the seven day average also had a difference that exceeded the allowable increase. The other occurrences were not part of a trend, which would be expected to occur if the event were a real Project-caused temperature exceedance.

On December 13, 2003, the model simulated a Project increase of 2.5°C when the allowable increase was 1.9°C. Because the simulation indicated that the Project had a difference of -2.5°C one week prior and a high variability of data surrounding these dates, this occurrence ~~appears to be the result of temporary model instability~~seemed to be the result of a discrepancy (Figure 22). Upon analysis, it was discovered that there was an anomalous spike in the input data. The incoming water temperature observed at Wells Dam increased by 2.4°C between December 4th and 6th, 2003. The temperature decreased by 2.7°C in one day from December 11th to 12th, 2003. Because Beebe is located very close to the Wells Dam, this spike did not create a temperature difference at Beebe because the warm spike reached Beebe at the same time under each scenario. However, due to the retention time of the entire reservoir, this spike reached the forebay a day or two earlier under the without Project than with Project, causing a temperature difference between the two scenarios. It is highly unlikely that this temperature spike was real; rather, it was likely the result of faulty input data, collected in the winter months when data are not as rigorously evaluated. ~~. It is difficult to imagine that a heat wave in late December caused the Project's effect to be several times greater than anything observed in the summer (Figure 22).~~

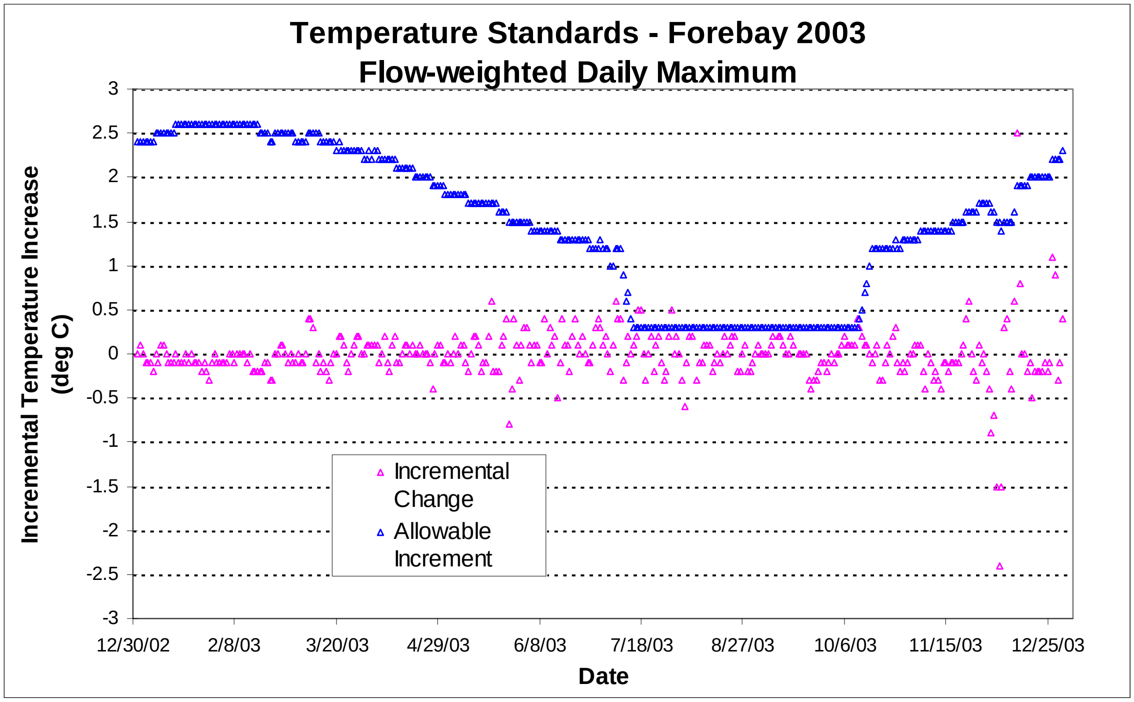


Figure 22: Temperature increase versus allowed for 2003 forebay simulation

The model was also used to compare the Project impact to proposed water quality standards, which consider a seven-day average of daily maximum temperatures and a criterion temperature of 17.5°C. On only one occasion between 2000 and 2004, August 16, 2001, was the simulated project impact greater than the acceptable incremental increase. The simulated Project effect was 0.4°C; the acceptable increase on that day was 0.3°C.

2.6 Oil and Grease Containment and Spill Prevention Control and Countermeasure Plan

2.6.1 Oil and Grease Containment

The Rocky Reach Project has installed oil/water separation facilities on wastewater sources, which are maintained and periodically upgraded to current technology standards. There are no polychlorinated biphenyls (PCB)-contaminated oils used on the Project. All powerhouse drains that have the possibility of being contaminated with oil flow into one principal collection system, the unwatering gallery. This gallery runs the length of the powerhouse at the 564 elevation. The unwatering gallery has two channels to separate oily and clean water. The clean water channel receives drainage from the draft tube doors, the service bay in the powerhouse, and gate sill drains. All floor drains near the units flow into the oily water channel.

Oil sources which can enter the powerhouse substructure drainage system are as follows:

- Generator thrust bearing pots - (4,000 to 5,600 gallons per unit);
- Turbine guide bearings - (50 to 75 gallons per unit);
- Governor sumps and accumulator tanks - (2,500 to 4,500 gallons per unit); and
- Governor wicket gate servomotors - (300 to 375 gallons per unit).

An oil skimmer and an oil separator are installed in the oily water channel at the south end of the powerhouse. A weir prevents oil from reaching the end of the channel. Ahead of the weir, the skimmer sucks collected oil into the separator. Water behind the weir flows into the clean water channel. Following separation, additional water enters the clean water channel while the oil is pumped up to a holding tank on the 630 elevation. Once water is separated, waste oil is pumped to two 4,500-gallon storage tanks equipped with alarms. The clean water channel has a 16-inch drain at its southern end which leads to the station sump, then the river. All other sites where oil is used or stored are either equipped with site-specific containment facilities or otherwise prevented from leaking oil into the waterways through best management practices, as described in the SPCC Plan.

A new WDOE initiative, the Columbia-Snake River Spill Response Initiative, was proposed to the Chelan PUD in the fall of 2004. Chelan PUD understands this initiative to be a uniform means for hydroelectric projects to identify appropriate sites and subsequently implement additional spill abatement technologies for oil, as needed. To date, Chelan PUD has conducted a preliminary investigation of the sites discussed during the initial WDOE proposal. A feasibility study is underway with the expectation that one site will be implemented by year end. Chelan PUD is still not entirely certain of the intent and sideboards of this initiative, and further guidance will be requested from WDOE as needed. As the plan is further developed, it will be included as an appendix to the SPCC Plan.

2.6.2 SPCC Plan

The Project has a SPCC Plan, which was last revised in July 2005 (available upon request). This SPCC Plan has been developed to address the storage and management of petroleum products at the Project to fulfill the requirements of 40 CFR 112, EPA Oil Pollution Prevention Regulations. The plan describes practices, procedures, structures, and equipment at the facility to prevent spills and to mitigate or preclude any adverse impact on the environment. The Oil Pollution Prevention Regulations (40 CFR 112) which became effective in 1974, were established for the prevention of water pollution by oil discharged from "non-transportation related onshore and offshore facilities." According to this regulation "non-transportation-related onshore and offshore facilities" include:

> "Industrial, commercial, agricultural, or public facilities which use and store oil, but excluding any terminal facility, unit, or process integrally associated with the handling or transferring of oil in bulk to or from a vessel."

The Project is included under these regulations as a "non-transportation-related onshore facility" (Sections 112.1(b)), located on the Columbia River. Secondarily, the Project stores greater than 1,320 gallons of oil in above ground storage tanks (Section 112.1(d)(2)).

It is the policy of Chelan PUD and all its contractors to recognize that oil contamination of the waters of the State of Washington is harmful. Therefore it is required that emphasis be placed on oil spill prevention, and that the latest engineering and safety procedures be used at all times when dealing with oil storage devices and associated equipment. In accordance with 40 CFR 112.5(b), a review and evaluation of this SPCC Plan is conducted at least once every five years.

Chelan PUD will amend the SPCC Plan within six months of the review to include more effective prevention and control technology if: (1) such technology will significantly reduce the likelihood of a spill event from the facility, and (2) if such technology has been field-proven at the time of review. Additionally, the Plan will be modified if a spill larger than 1,000 gallons occurs, or more than one spill of more than 42 gallons occurs within any twelve month period, or if there is a change in the facility design, construction, operation or maintenance that materially affects its potential for a discharge. Any technical amendment to the SPCC Plan shall be certified by a Washington State Professional Engineer within six months after a change in the facility design, construction, operation, or maintenance occurs which materially affects the facility's potential for the discharge of oil into or upon the navigable waters of the United States or adjoining shorelines.

SECTION 3: MANAGEMENT CONSIDERATIONS AND OPTIONS INVESTIGATED

3.1 Total Dissolved Gas

3.1.1 Operations to Limit Gas Uptake

Spill operations are managed for the purposes of promoting fish survival, adult passage efficiency, and limiting TDG entrainment. Spill is used as a tool in meeting the HCP survival objectives for downstream migrant salmon and steelhead. Spill is not the preferred tool because it has low fish passage efficiency and it is very expensive. However, at this time spill is considered necessary to augment the fish survival benefits of the juvenile bypass system. Future use of spill as a HCP fish survival tool is discussed further in section 3.1.4. In 2003, fish passage spill was provided to cover 95% of the time period of the run of each species. Spill levels in 2003 were 15% of the daily average flow for spring and summer migrant Chinook and steelhead and 25% of the daily average flow for sockeye. These daily average spill percentages were shaped to provide greater volumes of spill during the afternoon and evening, when most fish pass the project, and less spill from late night-early morning, when fewer fish are passing (Table 5:). The actual volume of flow is set ahead of time based on projected daily average flows, thus the actual instantaneous flow distribution between the powerhouse and spillway varies from the percentages in Table 5 as total river flow varies from hour to hour.

Table 5: HCP Juvenile Fish Passage Spill as Percent of Flow in 2003

Time of Day (hour period)	Early Season (4/20-5/8) (Chinook & steelhead)	Mid Season (5/9-5/29) (25% spill for Sockeye)	Late Season (5/30-8/14) (Chinook & steelhead)
0000-0100	15%	25%	15%
0100-0900	10%	15%	10%
0900-1600	15%	25%	15%
1600-2400	20%	35%	20%

Reduced spill levels were set for 2004 because the juvenile bypass system met the performance levels expected to achieve the HCP survival objectives of 95% with less spill. Spill in 2004 was set at 0% of the daily average flow for spring Chinook and steelhead, 24% for sockeye and 9% for subyearling Chinook. The same spill levels are planned for 2005, except that a test comparing spill and no spill will be conducted during the sockeye migration. Depending on results of the sockeye spill study, the same spill level may continue for three years during survival tests. However, spill may be further reduced or increased in the future based on results of the sockeye study and survival studies that will indicate if the HCP survival objectives are being met.

Spill, when necessary, is initiated and concluded based on the timing of the migration of each fish species. Sockeye spill (24% of flow) begins when 2.5% of the run has passed the Project, which typically occurs between the last week in April and the second week in May. Sockeye spill levels then continue until 97.5% of the run has passed the project, which usually is 25 days or more. Spill for subyearling Chinook begins at the end of sockeye spill or when the first subyearling Chinook is captured, then continues until 95% of the run has passed the Project (late July to early August).

The spillgate pattern used during the adult fish passage season (March – November) is designed to provide proper conditions in the tailrace to prevent delay of adult salmon and steelhead finding the entrances to the adult fishway. This spillgate pattern, referred to as the "standard" spill pattern in the near-field effects study (COE, 2003), uses spillgates 2-8 opened at different settings in order to create an inverted "V" of aerated water and water velocities projecting downstream from the spillway. Radio telemetry studies of adult salmon and steelhead have shown that this flow pattern prevents fish from being lead away from the fishway entrances by false attraction to spillway flows and, when properly shaped, prevents cross currents from confusing fish and creating a hydraulic barrier in the vicinity of fishway entrances. The standard spillgate pattern uses three gates at spill levels up to 20,000 cfs, and then adds gates one at a time until all seven gates (2-8) are open. The setting of the individual gates is adjusted for each incremental increase in spill discharge to maintain the desired flow characteristics in the tailrace. The individual gate settings used during the near-field effects study are shown in Figure 23.

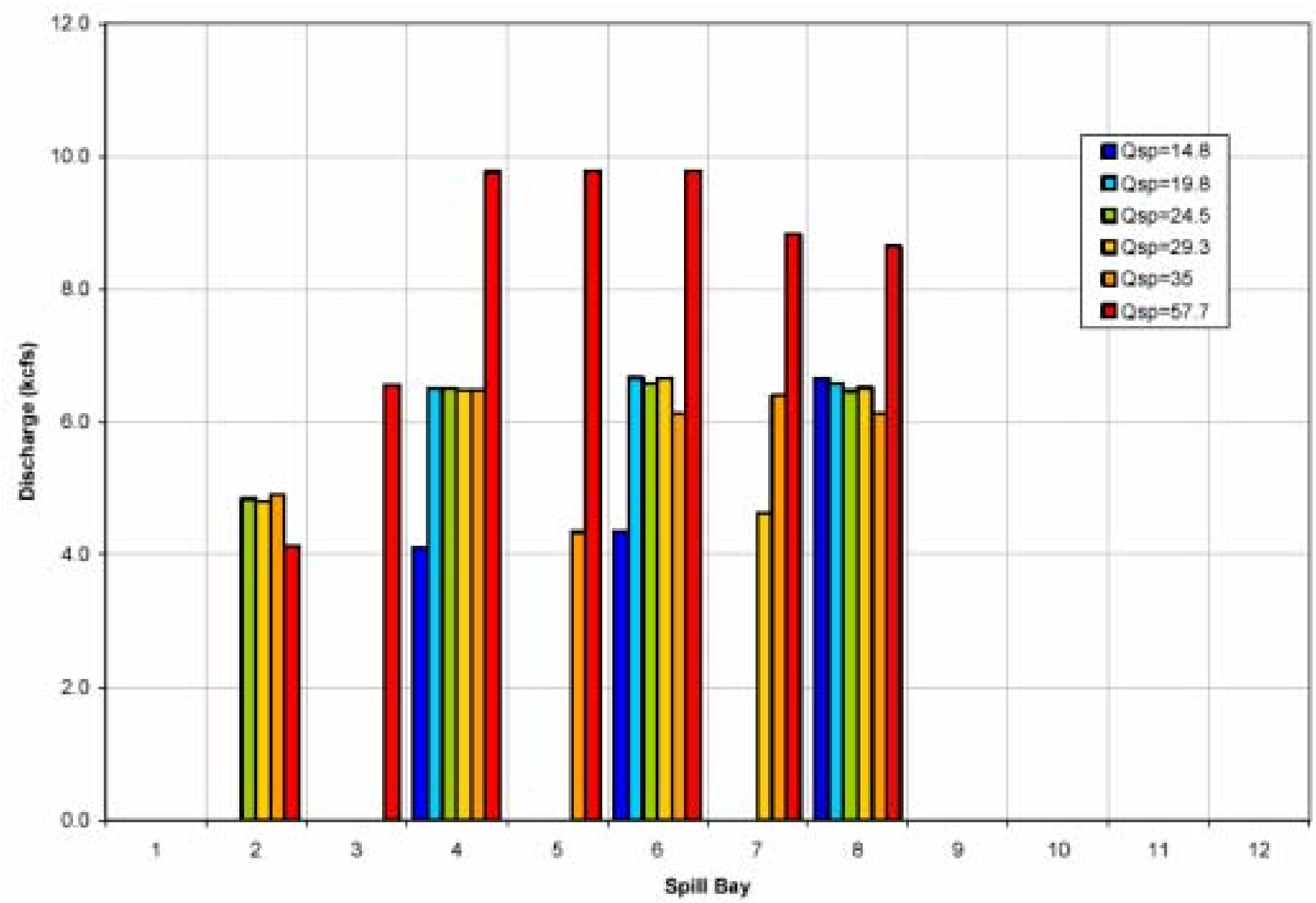


Figure 23: Standard Spill Pattern at Rocky Reach Dam Used During the Fish Passage Season (Flow Levels Indicated by Color Bars Are the Total Spillway Flows in kcfs That Were Used in the Near-Field Effects Study)

The spill level that is set for fish passage survival is subject to real-time modification to meet TDG standards, in accordance with the Rocky Reach Operational Plan for Total Dissolved Gas (TDG Operational Plan, Appendix D). The Project operators are instructed to monitor the tailrace TDG level and reduce spill if TDG levels specified in the TDG Operational Plan are exceeded. The operators at the Rock Island Hydroelectric Project are also instructed to inform the operators at Rocky Reach when the Rock Island forebay TDG level exceeds 115%. In 2003, these operations prevented any exceedances of the TDG criteria for the tailrace and no exceedances in the Rock Island forebay that were caused by spill from the Rocky Reach Project. There were two exceedances of 115% in the Rock Island forebay, but both were concurrent with exceedances in water arriving at the Rocky Reach forebay. As previously discussed in Section 2.4.2.3, this real-time response to spill management has also contributed to low TDG levels at the Rocky Reach downstream and Rock Island forebay fixed monitoring sites. The TDG levels in 2004 at the downstream fixed monitoring site remained below 113.1% during the 24% sockeye spill period, and below 114.6% during the 9% summer spill period. Fish passage spill ranged from 15-45 kcfs during the sockeye spill period and 5-20 kcfs during the summer spill.

3.1.2 Biological Effects of TDG

The biological effects of TDG on aquatic life are monitored as part of the regional effort to control TDG throughout the Columbia River. The Fish Passage Center (FPC) administers the program, which samples downstream migrant juvenile salmon and steelhead and monitors several aspects of the fish migration, including the incidence of GBT. The FPC summarized the results of the past seven years of monitoring for GBT in a recent letter (FPC, 2003), as follows. “Based on seven years of data from the biological monitoring program, the average incidence of gas bubble disease signs has been low, although the state-allowed maximum TDG due to spill was 120% in the tailrace and 115% in forebays during periods of voluntary spill. A high percentage of the spill that did occur in some years was involuntary and often resulted in dissolved gas levels above the 120% waiver. The following graphs (Figure 24 and Figure 25) depict the incidence and severity of signs of GBT in fish collected for observation over the seven years, grouped in 5% TDG levels. Increases in the incidence of signs were observed with increases in the levels of TDG. The severity of signs also increased, but not until dissolved gas levels were above the 120 to 125% level. These data suggest that TDG concentrations above 125% may have had a negative impact on survival. These high TDG measurements are a function of uncontrolled spill that occurred in the hydrosystem because of flow in excess of the hydraulic capacity of the project, or due to spill in excess of generation needs. They are not caused by the implementation of the Biological Opinion Spill Program. All of the information collected to-date of survival and the benefits associated with spill indicate that spill provides a significant benefit to juvenile survival at levels up to 125% in the tailrace of the dam.” This benefit to survival is based on the observations in the region that juvenile salmon passing through spillways typically have a survival rate of better then 98%, whereas the survival rate for juvenile salmon passing through powerhouses is often less than 95%. Since no mortality to salmon migrating in the river has been observed at TDG levels below 125%, there is a survival benefit. In Figure 24 and Figure 25, the GBT symptoms are classified by rank. Rank 1 is if 1 to 5% of the fin or eye is covered with bubbles; rank 2 is assigned for 6 to 25 % area covered; rank 3 for 26 to 50 % area covered; and rank 4 for greater than 50 % area covered. A “ST Rank” is a steelhead ranking.

The National Marine Fisheries Service (NMFS, presently NOAA Fisheries) conducted risk assessments of the fish passage TDG criteria (120% tailrace, 115% forebay of dams) in 1995 and 2000 in support of the FCRPS Biological Opinion. In the 2000 risk assessment (NMFS, 2000), the results of field and laboratory studies were reviewed and compared to the results of GBT monitoring and other research evaluating the biological effects of the spill levels and resultant TDG levels from 1995-1999. The analysis was focused on determining whether there was any adverse effect on fish survival resulting from the additional 10% in TDG levels from spilling up to the 120% "gas cap" of the FCRPS Biological Opinion. The accumulated data on GBT in Chinook and steelhead indicated that few GBT signs were observed when TDG level was below 120%. When fish with GBT symptoms are exposed to TDG levels greater than 120%, there is an increasing trend in incidence and severity of GBT. However, only a few fish with severe signs were detected until TDG levels approached 130% and GBT symptoms do not begin to increase in prevalence until TDG level is between 121-125%. For adult salmon and steelhead, generally no fish or very few fish were observed to have GBT symptoms when TDG levels were below 120%. NOAA Fisheries found little evidence that the survival benefit from the spill program would be reduced at all due to GBT-related mortality (NMFS, 2000). NOAA Fisheries concluded that the apparent inconsistency between the national 110% TDG criterion and the lack of adverse effects observed at a TDG level of 120% is due to the effect of depth compensation resulting from the observed migrating depth of adult and juvenile salmonids.

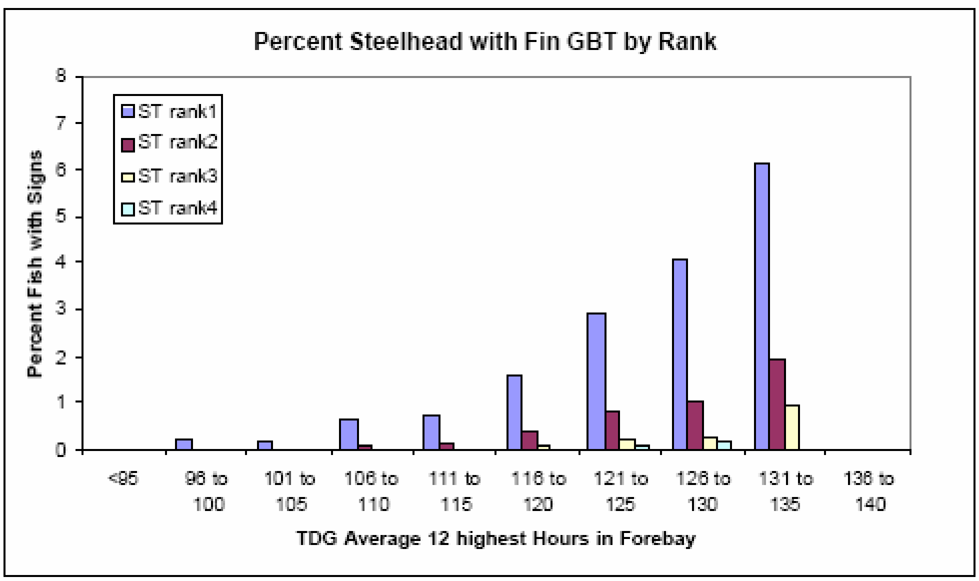


Figure 24: Incidence of Steelhead Smolts with GBT Over Seven Years of Monitoring at Federal Hydroelectric Projects (FPC, 2003)

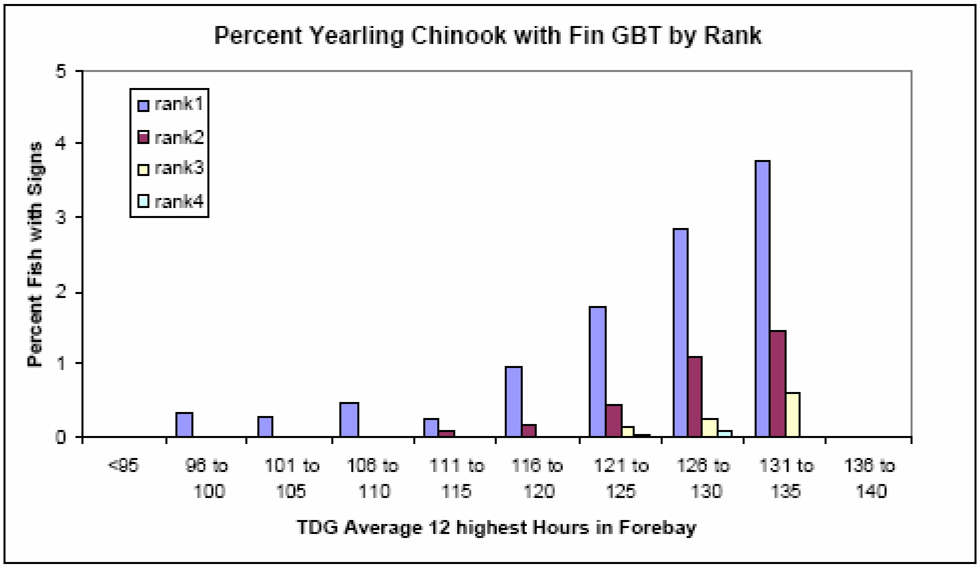


Figure 25: Incidence of Chinook Smolts with GBT Over Seven Years of Monitoring at Federal Hydroelectric Projects (FPC, 2003)

Chelan PUD's contribution to the regional effort is to provide the facilities and support for the FPC smolt monitoring program at Rock Island Dam. The incidence of GBT has been monitored at Rock Island Dam since 1985, and is reported by the FPC. Due to the nature of the trapping facility, the Rock Island monitoring site typically has higher incidences of GBT than at other sampling locations due to fish being trapped over a 24-hour period and held in a shallow flume. Even though this monitoring site is known to induce GBT by holding fish in shallow troughs overnight prior to examination, the level of GBT symptoms observed in 2003 remained below 5% (GBT at other Columbia River sites in 2003 averaged less than 1%). The GBT monitoring at Rock Island Dam has consistently reflected the trends noted in the other regional GBT monitoring programs, with no significant increases in GBT or incidence of severe GBT symptoms until TDG levels approach or exceed 125%.

The effect of TDG levels on other fish species besides salmonids has also been studied. NOAA Fisheries (NMFS, 2000) reported that the sensitivity of resident fishes and invertebrates to TDG levels greater than 110% was investigated in the early 1990's. Fish species observed for GBT signs included suckers, sculpins, sticklebacks and several minnows as well as crayfish, clams, and insect larvae. Gas exposure levels ranged from 117 to 130%. Only rarely were GBT signs observed. It was concluded that resident fishes and invertebrates are relatively tolerant of elevated TDG.

The biological effect of TDG on resident fish and benthic invertebrates below Rocky Reach Dam was studied in 2001 and 2002. Since there was no spill at Rocky Reach in 2001, the results from that year provided a good baseline for the study in 2002, when TDG levels reached 120% and briefly exceeded 130% in the tailrace. Since only a few hours of exposure to TDG levels above 120% can result in GBT symptoms in fish, the results of the 2002 study would have been expected to show high GBT if the resident fish and benthic invertebrates inhabited shallow waters or the fish preferred to reside near the water surface. Fish and invertebrates inhabiting deeper water (less than 10 feet depth) generally would not be exposed to elevated TDG because of compensation from hydrostatic pressure. The incidence of GBT in resident fish and benthic invertebrates was very low in both 2001 and 2002 (Parametrix and RL&L 2003). In 2001, there were no signs of GBT in the 3,777 resident fish examined, and only two cases of GBT in the 7,405 invertebrates examined.

In 2002, a total of 2,134 resident fish were examined during weekly sampling events during the spring monitoring period (April 19 to June 26, 2002). None of the fish exhibited any signs of GBT, despite being collected from shallow water where the maximum effects of TDG supersaturation are expected. The TDG levels during the spring spill season ranged from 103 to 127%.. The first signs of GBT occurred during the first summer sampling event (on July 9), conducted about a week after the peak TDG levels occurred (134%). Most of the signs consisted of slight hemorrhaging between the fin rays, at the base of the fins and in the lateral line. A total of 866 resident fish were examined for GBT signs during the summer monitoring period (July 9 to August 21), of which 160 (18%) exhibited GBT signs. However, some fish exhibited more severe signs such as subcutaneous hemorrhaging and swelling of the caudal peduncle and opercle, as well as hemorrhaging in multiple fins. Despite the relatively high incidence of hemorrhaging, actual bubbles were observed in only one fish (in the branchiostegal of a stickleback).

In 2002, benthic macroinvertebrates were collected from six sites downstream from the Project to assess the incidence of GBT and to evaluate the potential effects on community structure. With one exception, these sampling sites were similar to those sampled in 2001. Samples were collected during early April, early June, and early August. The sampling design incorporated dual sampling depths to collect benthic invertebrates from (1) potentially high TDG and low hydrostatic water pressure (shallow depth) habitats (0.5 m depth), where GBT is most likely to occur, and (2) areas where hydrostatic water pressure would compensate for TDG levels of up to 130% (3 m depth). One bristle worm and one mayfly (Ephemeroptera; Ephemeridae, Hexagenia) from Sites 3 and 6, respectively, exhibited signs of GBT. These animals comprised 0.02% of the total number of specimens examined (n = 9,885), and were collected from the 3 m sampling depth during the August and June sampling events, respectively. These results were surprising because the specimens showing signs of GBT were collected from a depth where the effects of the increased total gas pressure were not expected to occur, due to the hydrostatic pressure compensation provided by depth. The results obtained in the present study were comparable with the Rocky Reach TDG studies conducted in 2001 and by other researchers. Specifically, low incidences of GBT were observed in benthic macroinvertebrates under a considerable range of gas saturation levels.

A preliminary assessment was also conducted in 2002 to examine the ‘worst-case’ scenario for the development of GBT in macroinvertebrates. Single replicate artificial substrate baskets (previously colonized) were suspended at 1 m depth for up to seven days during the June and August field sampling programs. These samples represented the ‘worst case’ condition, because of their constant exposure to elevated TDG levels. In contrast, artificial substrates placed on the river bottom could periodically be exposed to lower TDG levels due to hydrostatic gas pressure compensation resulting from fluctuating water levels. However, none of the 404 invertebrates examined from the substrates suspended at 1 m depth exhibited signs of GBT. These findings imply that benthic macroinvertebrates are highly resistant to the effects of elevated levels of TDG.

The results of GBT monitoring and studies in the areas downstream of the Project have demonstrated that there is little, if any, adverse biological effect to migrant salmonids, resident fish species or macroinvertebrates at the TDG criterion level of 120%. These findings are consistent with research and monitoring conducted at other hydroelectric projects in the Columbia and Snake rivers. A GBT monitoring program is an effective method to assure that management of spill and TDG levels to meet the fish passage TDG criteria is protecting the aquatic life below the Project.

3.1.3 Operational and Structural Modifications Considered

Chelan PUD funded a review and synthesis of operational and structural methods used in TDG abatement efforts at other hydroelectric projects and an assessment of the applicability of those structural methods to the Rocky Reach Project (Montgomery Watson Harza [MWH], 2003). Subsequently, Chelan PUD funded a study by the U.S. Army Engineer Research and Development Center (ERDC) to further evaluate the efficacy of the options identified by MWH (Schneider and Wilhelms, 2005). These assessments were made by experienced personnel from ERDC who have conducted most of the research on TDG levels before and after TDG abatement measures have been taken at the COE dams and other hydroelectric projects on the Columbia and Snake rivers, including the near-field effects study conducted at Rocky Reach Project in 2002.

The MWH review included examination of TDG structural abatement actions studied by the COE, in their extensive program for dissolved gas abatement at federal dams on the Columbia and Snake rivers, structural abatement studies at other hydroelectric projects, and interviews with regional and national experts on TDG abatement methods. The synthesis consolidated the body of work into general types of abatement structural approaches, alternatives that prevent entrainment of air in the discharge, different spillway designs, designs to keep turbulent, aerated water near the surface, and alternatives to limit mixing of aerated water with other waters in the tailrace. The potential to apply these methods to the Project was described and each approach was evaluated in regard to a matrix of seven criteria. These criteria were: potential for TDG reduction; safety for downstream migrant fish passage; potential effects on adult fish passage; feasibility for maintaining project safety by passing probable maximum flood; impacts to generating capacity; impacts to public recreational use of the river; and impacts to operation and maintenance costs. The capital cost of construction was also estimated. Operational approaches consisted of limiting spill by maximizing powerhouse hydraulic capacity and reducing the need for fish passage spill and reducing the spill per individual spillgate, as described in the near-field effects study (COE, 2003).

The alternatives identified by MWH that prevented the entrainment of air in the discharge, which involved a pressurized discharge, were submerged outlets (S2, S3), new spillway gates (S12), convert turbines to sluices (S13) and adding a new powerhouse (S16). All of these alternatives were very expensive and exposed downstream migrating fish to possible injury. Some also had limited feasibility for structural or other reasons. Of these, only the additional powerhouse, which could be equipped with a fish bypass system or fish-friendly turbines, was considered remotely feasible from a technological perspective (but not from a financial perspective). However, an additional powerhouse was not recommended by MWH for further study because other alternatives show more promise.

Alternatives to add additional spillways, or replace existing spillways with different designs, were baffled spillway (S4), side channel spillway (S5, S6), and V-shaped spillway (S15). All but one of these alternatives would involve a channel around the left abutment, extending downstream for distances up to 1,000 feet or more. The V-shaped spillway would require replacement of the existing spillway. These alternatives all had extremely high construction costs (more than $100 million), the downstream fish passage survival or passage efficiency is unknown for these hypothetical spillways, and all these options are likely to adversely affect adult passage. For these reasons, MWH did not consider these options to be feasible.

The alternative to prevent mixing of powerhouse flow with aerated water from the spillway, a divider wall between the powerhouse and spillway (S17), was judged to be very costly. The limited TDG abatement would only reduce average TDG levels below the Project's tailrace by a small amount and would not improve TDG levels in the spillway flow.

The alternatives that keep turbulent, aerated water near the surface or reduce air entrainment, which included abatement options employed or considered for use at federal dams on the Columbia and Snake rivers, were spillway deflectors (S1), raised stilling basin (S8), raised stilling basin with deflectors (S9), raised tailrace (S10), raised tailrace with deflectors (S11) and removal of the nappe deflectors (S18). The MWH report recommended that these alternatives be considered for further evaluation because they are technically feasible, although several would change the energy dissipation characteristics of the stilling basin, which could affect the tailrace hydraulics to the detriment of project structure erosion and adult fish passage attraction to fishway entrances. The main factor that MWH could not quantify about these alternatives relates to the potential improvement in TDG that would be achieved from implementation of these options. The spillway design at Rocky Reach already has a very shallow stilling basin and tailrace and the energy dissipation characteristics of the stilling basin may already accomplish as much TDG abatement as would the addition of deflectors. The Project already has a low TDG exchange relationship, comparable to the TDG exchange seen at federal projects after they have been equipped with spillway deflectors and other abatement technology. Also, the Rocky Reach stilling basin and tailrace are shallow in comparison to most dams on the Columbia River, with only The Dalles Project having a similar stilling basin and tailrace depth. At the Columbia and Snake river projects operated by the COE, the use of spillway deflectors is widespread at projects with deep stilling basins, but the COE decided not to install deflectors at The Dalles Project because its shallow stilling basin has good gas characteristics (Rock Peters, personal communication in MWH 2003). The Rocky Reach shallow stilling basin and tailrace are comparable to the situation at The Dalles Hydroelectric Project (where TDG levels are low due to shallow stilling basin), thus the incremental benefit of raising the stilling basin and tailrace on abatement of TDG may be too small to be meaningful.

The operational and structural alternatives recommended for further study by MWH were further analyzed by ERDC (Schneider and Wilhelms, 2005) to estimate the potential TDG reduction that could result from each option and if implementation would pose a risk of injury to juvenile salmon smolts passing through the spillway. Neither TDG abatement potential nor fish injury potential can be accurately predicted from model studies. However, there is considerable experience available from other Columbia and Snake river projects where these types of spillway modifications have been installed, or where the physical characteristics of the other project mimic the characteristics of the alternatives recommended for further consideration. The following analysis is based on a review of gas abatement achievements at other projects and best professional judgment about potential reduction in TDG levels that could be attained at Rocky Reach.

The ERDC technical assessment of the TDG management potential of the proposed operational and structural alternatives focused on the alternatives recommended by MWH and further analysis of an entrainment cutoff wall to partition powerhouse flows from the highly aerated spillway flows. The list of alternatives (MWH's option identifiers in parenthesis) reviewed by ERDC were as follows:

1. Maximize Powerhouse Flows (O1)
2. Spill from Gates 2 through 12 (O2)
3. Spillway Deflectors (S1)
4. Entrainment Cutoff Wall (S17)
5. Raised Stilling Basin (S8)
6. Raised Tailrace (S10)
7. Raised Stilling Basin with Deflectors (S9)
8. Raised Tailrace with Deflectors (S11)
9. Remove Nappe Deflectors (S18)

The configuration of the spillway and associated features dictates the level of TDG entrainment that is created by a given project. The bathymetry and hydraulics of the system downstream of the dam dictate the degassing that occurs in the tailrace. Some of the alternatives impact the gassing of the water, others the degassing in the tailrace and a few impact both. Below is a summary adapted from Schneiders and Wilhelms (2005) that presents each of the identified options, described in brief, and the outcome of the ERDC evaluation.

Maximizing powerhouse flows reduces spill because more of the total water flow is passed through the powerhouse, with static TDG levels. The current operating regime includes consideration for maximizing flows to reduce spill while operating for peak efficiency. Under the HCP, voluntary fish spill quantities are mandated based on the efficiency of the juvenile bypass system. Hourly Coordination is optimized to reduce spill at each of the affiliated projects. These and any future identified opportunities to reduce spill will be implemented, as described in section 4.

Currently at Rocky Reach, the standard spill pattern consists of spilling water in varying volumes from Bays 2-8 (Figure 23). The second alternative evaluated would change the flow pattern during high flows from that standard spill configuration to spread release of water from Bays 2-12. The specific spillway discharge, or discharge per foot of lateral distance, has been found to be an important determinant to TDG exchange at many projects in the Columbia River Basin. A comparison was made of 56 kcfs spill from Bays 2-12 to 57.8 kcfs spilled using the standard spill pattern (Bays 2-8). The powerhouse discharge was higher and the forebay TDG concentration lower when spill occurred using the standard spill pattern (Bays 2-8), than during the spill through Bays 2-12. If the two spill patterns were the same, the dilution of the powerhouse waters should have yielded a lower TDG in the mixed flow for the standard spill pattern (Bays 2-8) than for the spill through Bays 2-12; however, the reverse was observed, indicating that spilling from Bays 2-12 may reduce the TDG levels in the mixed flow. Based on observations, it has been estimated that spilling from Bays 2-12 may reduce TDG levels in the mixed flow by up to 2%.

This reduction in the TDG loading from Rocky Reach Dam was apparent in the average cross-sectional TDG levels measured below the dam. The peak TDG levels, as observed at station FOP1, were similar for the standard spill pattern (Bays 2-8) and the Bay 2-12 spill pattern sampled during this field study. Spilling from Bays 2-12 may have greater applicability during forced spill events when spillway discharge exceeds 50 kcfs and the powerhouse is fully loaded at about 200 kcfs. The quantitative TDG abatement potential of spilling from Bays 2-12 instead of using the standard spill pattern (Bays 2-8) remains to be evaluated. Additional field-testing was recommended to further identify the TDG abatement benefits of applying a spill pattern over Bays 2-12.

The third alternative evaluated was the use of spill deflectors. Spillway flow deflectors have been one of the primary methods for TDG management on lower Snake and Columbia River dams. Ideally, deflectors are positioned on the spillway to redirect flow across the surface of the tailwater. This reduces the plunging action by which the spillway flow transports entrained air to the full depths of the stilling basin. By reducing the mean depth to which entrained air is transported, the level of TDG absorption can be reduced.

Although the addition of spillway flow deflectors has provided significant TDG abatement benefits at many mainstem Columbia and Snake River dams, it appears to have a limited potential TDG benefit at Rocky Reach Dam. The TDG exchange properties at Rocky Reach Dam are comparable with, and in many cases superior to, the TDG exchange attributes observed at Lower Granite Dam, a project with spillway flow deflectors properly functioning on all eight spillbays. The relatively low rates of TDG exchange observed at Rocky Reach Dam can be attributed to the shallow stilling basin, high rate of energy dissipation, relative size of the spillway, and influence of the sloped end sill. It is possible that a spillway flow deflector could increase the TDG exchange properties at Rocky Reach Dam by extending the zone of highly turbulent aerated flow conditions into the deeper tailrace channel below the stilling basin. Schneider and Wilhelms (2005) concluded that the spillway flow deflector alternative for Rocky Reach Dam has a low probability for providing effective TDG management.

The fourth option evaluated was the implementation of an entrainment cutoff wall. This option was not recommended by MWH, but was included by Schneider and Wilhelms, based on their observations of the Project and experience. The orientation of powerhouse and spillway discharges at Rocky Reach Dam has a strong potential to interact quickly within the stilling basin and adjoining tailwater channel. The powerhouse discharge is directed laterally across the channel and into the path of highly aerated spillway releases. A return current flowing from the powerhouse discharge into the stilling basin was evident during spillway release TDG testing conducted in 2002. A depression of the tailwater stage within the stilling basin was noted during these spill events resulting in a strong current being directed into the stilling basin downstream of Bay 2. The turbulent energy contained in spillway releases has a large potential to entrain nearby water from powerhouse releases.

If the entrainment of powerhouse flows into spillway flows occurs in highly aerated and turbulent flow, the resultant TDG loading can be increased significantly. The component of powerhouse flow entrained into aerated spillway flows will be exposed to the exchange of atmospheric gasses resulting in TDG supersaturation. The powerhouse flow not entrained, which typically contains lower TDG pressures than spillway releases, will be reduced and less able to dilute spillway releases downstream of the Project. A wall constructed between the powerhouse and spillway can prevent a substantial portion of powerhouse flows from becoming entrained and aerated within the spillway's stilling basin and tailwater channel. The resulting partitioning of project flows could also provide a larger volume of powerhouse discharges at a lower TDG level to dilute the high TDG pressures generated during spillway operations within the developing mixing zone. This alternative does not reduce the level to which the spill flows become saturated with dissolved gasses but reduces the total volume of flow exposed to aeration and elevation of TDG pressure. In this way, it reduces the total mass of TDG produced by spill.

The entrainment cutoff wall could provide the greatest degree of improvement when there is a large entrainment of powerhouse flow into the aerated spillway discharge and the ambient background TDG pressures are low. If the entrainment of powerhouse flows is small or background TDG levels high, the benefits of partitioning project flows with an entrainment cutoff wall will be small or negative. The reductions in average TDG level resulting from the entrainment cutoff wall for total river flows of 200 and 250 kcfs were 1.3 and 1.6 %, respectively. Determination of the detailed performance of an entrainment cutoff wall would require further study. An entrainment cutoff wall would likely reduce the total head for turbines at the north end of the powerhouse. The separation wall would need to be properly designed and constructed with adequate consideration for guidance of adult salmonids and steelhead because the main upstream fishway entrance would be affected by changes in tailrace flow patterns.

The fifth option evaluated was raising the stilling basin floor. Raising the stilling basin apron reduces the depth to which aerated spillway flow can plunge, thereby reducing the hydrostatic pressures that the air bubbles experience. As a consequence, TDG concentrations in the stilling basin are reduced. The variation in elevation of the stilling basin floor at Rocky Reach Dam provides an opportunity to evaluate the influence of stilling basin depth on TDG exchange and hence the potential TDG benefits associated with raising the stilling basin floor. The stilling basin floor associated with Bays 9-12 at Rocky Reach dam at elevation 590 is about 5 feet higher than the stilling basin floor associated with Bays 2-5. The maximum TDG levels observed below the spillway at station FOP1 for uniform spill over Bays 2-5 were consistently lower than conditions observed during uniform spill over Bays 9-12. In general, the TDG level during spill over Bays 9-12 was from 1 to 2% higher than comparable spill over Bays 2-5 even though the stilling basin average depth of flow was less during the uniform spill over Bays 9-12. These observations suggest that simply raising the stilling basin floor may not have the intended effect of reducing the TDG level of spillway flows. The circulation pattern and air entrainment influenced by the nappe deflectors, impact baffles, and sloped end sill override the importance of the elevation of the stilling basin floor at Rocky Reach Dam.

The alternative of raising the elevation of the stilling basin at Rocky Reach Dam is likely to have a relatively small impact on the TDG exchange properties during spillway operations based on TDG exchange observations at Rocky Reach Dam as compared to similar observations at The Dalles Dam. Further consideration of this alternative was not recommended as an effective TDG management alternative at Rocky Reach Dam. Further consideration of this alternative would require a physical model study to assess the hydraulic performance of a modified stilling basin for a range of discharges and tailwater elevations up to the maximum probable flood flow.

The sixth alternative evaluated was raising the tailrace channel. A rapid and substantial desorption of supersaturated dissolved gas takes place in the tailwater channel immediately downstream of the stilling basin. As the entrained air bubbles are transported downstream, they rise above the compensation depth in the tailwater channel. While above the compensation depth, the air bubbles strip dissolved gas from the water column. Field studies have shown that gas absorption occurs in the stilling basin and significant degassing occurs in the first 200-300 ft downstream of the stilling basin.

Raising the tailrace channel bottom at Rocky Reach Dam is likely to be an ineffective measure of TDG management because most of the TDG exchange occurs in the surface oriented jet exiting the stilling basin, which is not limited by the tailwater channel depth and associated depth of plunging flows. Adopting this alternative would also require a physical model study to assess the hydraulic performance of the tailrace for a range of discharges and tailwater elevations up to the maximum probable flood flow. Since the tailrace fill material would require protection from scour, riprap or other protection would have to be considered.

The seventh alternative evaluated was raising the stilling basin floor combined with installation of spillway flow deflectors. A raised stilling basin with spillway flow deflectors is a combination of alternatives that individually were identified to have limited application at Rocky Reach Dam to manage TDG level in spillway flows. The addition of spillway flow deflectors that create a surface jet would negate the effects of raising the stilling basin floor by preventing the transport of entrained air to depth. The effectiveness of a raised stilling basin floor would become influential when spill discharges begin to override the flow deflector, creating a plunging aerated jet. Typically, flow deflectors become ineffective only at very large specific discharges, which would be much greater than the spill discharge range targeted at Rocky Reach Dam to manage TDG exchange up to the 7Q10 flow. As a consequence of these factors, the raised stilling basin with spillway flow deflectors is identified as having very limited potential to effectively manage TDG exchange at Rocky Reach Dam.

The eighth alternative evaluated was raising the tailrace channel combined with installation of spillway flow deflectors. The combination of spillway flow deflectors to minimize the initial plunge of entrained air in the stilling basin and a raised tailrace channel that promotes the stripping of TDG pressures has proven to be an effective TDG management feature. The construction of spillway flow deflectors with a raised tailrace channel at Rocky Reach Dam may result in an improvement in TDG management of the Columbia River. The ability to implement this alternative would require a substantial modification to the stilling basin and tailrace channel at Rocky Reach Dam. Nappe deflector removal would be required to properly site the spillway flow deflectors. This alteration would greatly reduce the energy dissipation properties of the stilling basin. The tailrace channel would probably need to be armored to withstand the large hydraulic forces associated with spillway flow deflectors in place. The tailrace channel would have to be raised to elevation 608 to achieve the depths and TDG exchange performance demonstrated at Ice Harbor Dam, the dam that exhibits the lowest TDG exchange properties of dams actively spilling for fish passage in the Columbia River Basin. The raised channel would extend about 300 feet below the stilling basin at Rocky Reach Dam and would be located downstream of Bays 2-12.

The final alternative evaluated was the removal of the nappe deflectors. The alternative of removing the nappe deflectors as a means of TDG management at Rocky Reach Dam was based on the concept of reducing the amount of air entrained into the spillway release. Although it is likely that a fully aerated nappe has the potential to entrain higher rates of air at the plunge point compared to a spill bound by the spillway channel, it is uncertain whether this higher air to water ratio results in an increase in the net mass transfer.

Bay 1 at Rocky Reach Dam does not contain a nappe deflector and could be used to test the TDG properties of this structural configuration. However, The Dalles dam has a standard ogee spillway with a stilling basin depth similar to Rocky Reach Dam. The resultant TDG exchange at The Dalles Dam was considerable higher than observed at Rocky Reach Dam over the full range of operations. The peak TDG level in spillway flow was anywhere from 2 to 10 % less at Rocky Reach Dam when compared to a similar specific spillway discharge at The Dalles Dam. The hydraulic action caused by the upstream baffle and end sill at Rocky Reach Dam are probably responsible to the different TDG exchange attributes between these projects.

The above reviews of operational and structural alternatives, consolidating the options identified by MWH and the analysis of ERDC are summarized in Table 6. This table includes the final assessment of feasibility based on efficacy, as determined by the ERDC (Schneider and Wilhelms, 2005).

Table 6: Review of Operational and Structural Concepts for TDG Abatement

Alternative		1) TDG Reduction *	2) Downstream Fish Passage **	3) Adult Fish Passage **	4) Maintaining Design Spillway Capacity **	5) Impact on Generating Capacity **	6) Use of River **	7) Operation and Maintenance **	8) Capital Cost ($1,000) **	MWH Recommended for Further Investigation	ERDC Recommended for Further Investigation	Remarks
O1	Maximize Powerhouse Flows	+	0	0	0	0	0	0	$0	✓	✓	Can be implemented Sept. – Mar and, if bypass system meets survival standard, April-May.
O2	Spill from Gates 2 through 12	+	0	0	0	0	0	0	$0	✓	✓	Requires agency approval of new spillway operating plan.
S1	Spillway Deflectors	P	-	0	0	0	-	0	$14,279	✓		Removal of nappe deflector is included in the cost.
S2	Submerged Outlets	F	-	-	0	0	-	-	$21,587			
S3	Submerged Outlets with Deflectors	+	-	-	0	0	-	-	$35,866			Cost of S1 plus S2. Removal of the nappe deflector is included in the cost..
S4	Baffled Spillway	F	-	0	0	0	-	-	$220,952			
S5	Side Channel Spillway	+	0	0	0	0	-	-	$200,173			
S6	Side Channel Stepped Spillway	F	-	0	0	0	-	-	$168,718			
S7	Additional Spill Bays											Not Practical
S8	Raised Stilling Basin	P	-	0	0	0	-	0	$28,292	✓		Minimal spillway extension in cost
S9	Raised Stilling Basin with Deflectors	P	-	0	0	0	-	0	$36,998	✓		Cost of S1 plus S8
S10	Raised Tailrace	P	0	0	0	-	-	0	$6,966	✓		Might be slight impact on generating capacity
S11	Raised Tailrace with Deflectors	+	-	0	0	-	-	0	$21,245	✓	✓	Cost of S1 plus S10
S12	New Spillway Gates	F	-	-	0	0	-	-	>$100,000			No cost estimate available
S13	Convert Turbines to Sluices	F	-	-	0	-	-	-	>$100,000			No cost estimate available
S14	Hydrocombine Powerhouse	+	+	0	0	0	-	-	>$100,000			No cost estimate available
S15	V-Shaped Spillway	F	-	0	0	0	0	-	>$100,000			No cost estimate available
S16	Additional Powerhouse	F	0	0	0	+	-	-	>$100,000			No cost estimate available
S17	Divider Wall between Powerhouse and Spillway	+	0	-	0	-	0	0	$63,787		✓	TDG benefit for this alternative only at Rock Island Forebay compliance location.
S18	Remove Nappe Deflectors	P	0	0	0	0	0	2	$7,388	✓		There may be a need to modify the stilling basin, which is not included in the cost.

* Note 1

Score	Description
P	TDG remains the same as at present
+	TDG is improved over present conditions
F	TDG would be approximately that of the forebay

** Note 2

Score	Description
-	Less desirable than present conditions
0	Same as present conditions
+	More desirable than present conditions

MWH = Montgomery, Watson, Harza
ERDC = United State Army Corps of Engineers Research and Development Center (Schneider and Wilhelms, 2005)

3.1.4 Reduction in Use of Spill for Fish Passage

The HCP survival standard of 95% juvenile dam passage survival and 91% project survival (juveniles and adults combined) will be achieved by Chelan PUD through use of a number of tools. The principle method for meeting the juvenile survival standard is the new fish bypass system, completed in spring of 2003. Other tools include predator control, turbine operations set to maximize fish bypass system efficiency and minimize fish passage mortality, and spill, when necessary to supplement the other tools. The fish bypass system met expectations in its first year of operation; with fish bypass efficiencies for spring migrant Chinook and steelhead that are expected to achieve the survival standards without use of spill as a supplemental measure. In 2004, survival was measured for these species without spill and the survival rates met the standard. The fish bypass system achieved higher fish bypass efficiencies for sockeye and summer migrant Chinook than the prototype system it replaced, but Chelan PUD expects to improve on that performance as the operation of the fish bypass system is fine-tuned through experience. The level of spill, if any, that will be necessary to achieve the survival standard for any species, particularly for summer migrant Chinook and sockeye, will be defined based on the results of survival studies initiated in 2004 and the fish bypass efficiencies achieved through both the fish bypass system and the spillway. A study of sockeye passage, with and without spill, and survival studies for yearling Chinook and steelhead were conducted in 2005. Results of these studies will be available in spring, 2006.

Phase I of the HCP is the period that Chelan PUD has to implement its choice of tools and demonstrate achievement of the survival standards. Three years of survival studies for each species, each with valid statistical precision, are required to confirm that the survival standard has been achieved. Chelan PUD has set out an aggressive schedule to complete this confirmation period by 2007 or 2008, assuming that natural events (drought or flood river flows), inability to obtain test fish for the studies, or other problems do not prevent accomplishing the three years of study for each species. At the end of the studies, the HCP phase will change to either Phase III, survival standards achieved, or Phase II, survival not achieved. In Phase II, implementation of additional tools will begin and continue until the survival standard is achieved and Phase III is reached for that species. Additional tools could include more turbine intake screens, additional spill, and other bypass technologies that may be developed. When Phase III is reached for a species, then the level of spill necessary to maintain achievement of the survival standard will be set and the Project will operate in that mode until such time that improvement in the efficiency of the fish bypass system or the implementation of other tools accomplishes equivalent fish survival benefits. It is Chelan PUD's goal to pursue non-spill alternatives to achieve the survival standard for all species, to the extent that reasonable and feasible methods can be implemented. When Phase III is set for a species, the level of fish passage spill will be known and operations and other measures necessary to maintain compliance with water quality standards for TDG can be determined.

3.2 <u>Temperature</u>

3.2.1 Operations Options Considered

The CE-QUAL-W2 simulations of Rocky Reach Reservoir indicated that the Project generally met the current 1997 numeric criteria for water temperature during 2000-2004, the five-year period that was modeled. The difference in temperature increase between the with-Project and without-Project models was typically well below the allowable increase for human effects, as calculated on a daily basis. In only one case, using the 2003 proposed criteria (seven-day average of the daily maximum temperature) did the difference between the with- and without-Project exceed the criteria. The Project, as previously discussed, has only a small effect on the thermodynamics of heat exchange between the water in the reservoir and the influences of climate and solar radiation.

At other Columbia River projects, there are two operational options that have been considered for reducing the uptake of heat energy in their reservoirs. These options are related to increasing water velocity, thus reducing water residence in the reservoir, and reducing water levels, which affects both water velocity and surface area. The FCRPS has the option to increase river flow by releasing water from storage projects, such as Grand Coulee Dam. The benefits of increased water velocities are then experienced at all downstream projects. Another option is to reduce reservoir level, thus reducing surface area (exposure to contact with air and solar radiation) and increasing flow velocities, which reduces the length of time that water remains in the reservoir and is exposed to heating. These options have been considered for the Rocky Reach Project, but neither of them is feasible or beneficial for the reasons described below.

3.2.1.1 <u>Increase River Flow through Storage Release</u>

The amount of storage available from the Project is too limited to create a sustained increase in river flow that would be sufficient to affect water temperatures. Even if the reservoir could be drafted to minimum pool on a daily basis to increase flows during the daytime, the resulting flow increase would be less than 40,000 cfs. Further, these flows would not be experienced in the Rocky Reach reservoir, but in the downstream Rock Island Reservoir. The Wells Project would have to operate in the same manner to produce a similar effect in the Rocky Reach reservoir. Daily drafting and refilling of the reservoir would also have adverse ecological and aesthetic impacts. Further, this operation would void the benefits of the Hourly Coordination Agreement. The current operations under the Hourly Coordination Agreement already provide increased daytime flow rates greater than could be provided through use of individual storage releases from the run-of-river projects, such as the Rocky Reach Project. The FCRPS system currently provides augmented flow releases from Grand Coulee Dam during the spring and summer juvenile salmon migration, which has beneficial effects on water temperatures at all the downstream projects, including the Rocky Reach Project. Only a regional decision to increase summer flow releases from FCRPS storage projects could create a sustained increase in flows that could affect temperature increases through the Columbia River hydroelectric system. The small, run-of-river projects, such as the Rocky Reach Project, do not have this capability.

3.2.1.2 <u>Operate at Minimum Operating Pool</u>

The surface area of the reservoir would be slightly reduced and average velocity of water passing through the Rocky Reach reservoir could be increased slightly if the reservoir were operated at minimum elevation (704 for project safety and reliability). However, this three foot difference in reservoir elevation would not be sufficient to produce a measurable reduction in water temperatures. The increase in daily average temperature from creation of the Rocky Reach reservoir has been predicted by both the EPA RB10 model and the SNTEMP model to be typically less than 0.1°C (Figure 16) and no greater than 0.5°C under extreme conditions of low flow and high air temperatures. The CE-QUAL-W2 modeling indicated that the Project generally causes less than a 0.3°C increase to the daily maximum water temperature when the temperature is at or above 18°C. The pre-Project surface area of the reservoir's 43-mile reach of the Columbia River is estimated at 3,643 acres during summer flows, whereas the current surface area, with forebay at 707 elevation and 100,000 cfs flow, is approximately 8,235 acres. The reservoir surface area for the same flow at 704 forebay elevation is about 300 acres less than at 707. Thus, if creation of the reservoir caused less than a 0.1°C increase in daily average water temperature through an increase in surface area of 4,592 acres, then a reduction of 300 surface acres would proportionately yield less than a 0.007°C reduction in water temperature effects. Even during the extreme conditions of low flow and high temperature, operation at 704 would yield no more than a 0.03°C reduction in the daily average temperature effect of the Project. Therefore, operation at minimum pool would not substantively reduce water temperatures at the Project.

3.2.2 Structural Options Considered

3.2.2.1 <u>Selective Withdrawal</u>

At many hydroelectric projects, particularly those with high storage capacities relative to their discharge, the water in the forebay is thermally stratified at depth. At these projects it is feasible to modify the turbine intakes to allow water to be withdrawn from specific depths at different times of year. This type of structural modification, a selective withdrawal system, is a common method used to mimic natural temperature regimes in the powerhouse discharge or provide cooler water to benefit fish populations. The feasibility of this approach requires that the water in the forebay have a temperature gradient and that the turbine intakes be suitable for structural modifications to limit the water withdrawal to specific depths in the forebay.

At some hydroelectric projects, the reservoir in the vicinity of the forebay may have different temperatures on one side of the river than the other. This may occur when a major tributary (such as the Snake River upstream from McNary Dam) is warmer than the main channel and mixing of the two flow sources has not occurred. Lateral differences in water temperature profiles can also occur when one side of the river channel is out of the main flow, allowing greater warming due to a longer retention time.

At the Project, neither of these situations occurs. The water in the Project's forebay does not stratify and exhibits no temperature gradient except some limited afternoon warming of the surface waters (upper 3 m). Also, there are no apparent lateral differences in water temperatures across the reservoir upstream from the forebay. The lateral temperature data (Parametrix and Rensel, 2001; Parametrix and TRPA, 2002) indicate that the mainstem flow of the river is very well mixed with regard to temperature. In 2000, the water temperature was measured in vertical profiles at the thermograph locations on the reservoir, which included a station at the upstream extent of the forebay. In addition, lateral transects of vertical temperature profiles were taken at thermograph locations on August 17. In 2001, similar measurements were taken at similar locations. In 2001, the lateral transects of vertical temperature profiles were taken on September 2. The warmest temperatures were observed in shallower water in near-surface waters measured during the afternoon (Figure 26; Table 7:).

The Rocky Reach turbine intakes withdraw water from the forebay below the depth of 40 feet below the full pool elevation of 707. An ice-trash curtain wall at the face of the turbine intakes extends to elevation 666, thus reducing the availability of water in the upper 40 feet from entering the turbines. In essence, the structure of the turbine intakes is a selective withdrawal in that any surface water subject to daytime warming is not directly able to enter into the turbine intakes. Thus, there is no potential for structural modifications to the powerhouse that would reduce the water temperature of the powerhouse discharge. The powerhouse discharge already selects the coolest water available from the forebay. Similarly, the spillway draws water from a depth of about 50 feet at normal gate openings of 2-12 feet per gate. The spillway gates open from the bottom, allowing water from the ogee elevation of 649.6 to the elevation of the bottom of the gate (determined by the amount the gate is opened).

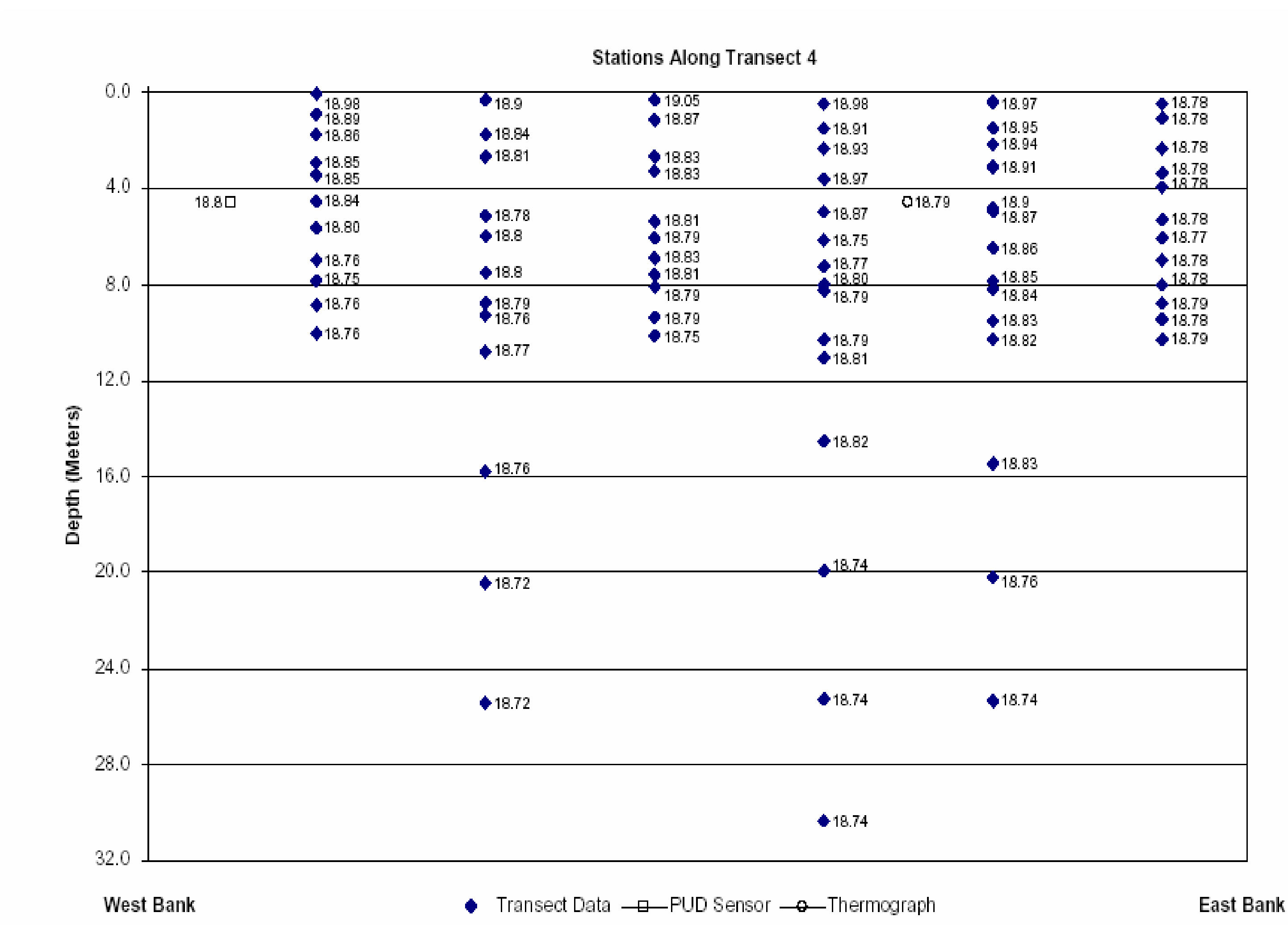


Figure 26: Water Temperature Transect Measurements at Rocky Reach Forebay Compared to Thermograph and Temperature Sensor Results; August 17, 2000

Table 7: Summary of Water Temperature Transect Measurements in Rocky Reach Forebay; September 2, 2001

	Transect 8 - Morning				Transect 8 - Afternoon			
Station	Depth (Meters)	Temperature (°C)	Temperature Difference (°C)	Mean Temperature (°C)	Depth (Meters)	Temperature (°C)	Temperature Difference (°C)	Mean Temperature (°C)
1	0	18.4	0.2	18.3	0.1	19.6	0.8	19.3
	1.3	18.2			2.8	18.9		
2	0	18.5	0.0	18.5	0.1	19.7	1.1	18.7
	25	18.5			25.3	18.6		
3	0	18.5	0.0	18.5	0	19.2	0.6	18.6
	30.8	18.5			37.1	18.5		
4	0	18.5	0.0	18.5	0	19.3	0.9	18.6
	38.8	18.5			39.8	18.5		
5	0	18.5	0.0	18.5	0	19.3	0.8	18.6
	38.9	18.5			38.2	18.5		
6	0	18.5	0.0	18.5	0.1	19.3	0.8	18.6
	37.1	18.5			38.3	18.5		
7	0	18.5	0.0	18.5	0	19.3	0.8	18.6
	33.6	18.5			34	18.5		
8	0	18.5	0.0	18.5	0	19.2	0.7	18.6
	37.8	18.5			38.1	18.5		
9	0	18.5	0.0	18.5	0.1	19.3	0.8	18.6
	28.6	18.5			25.2	18.5		
10	0	18.4	0.1	18.4	0	20.0	1.3	19.3
	4.8	18.4			2.7	18.7		

3.2.2.2 Modifications to Fishway Intakes / Sun Barriers

The Project has two fishway systems that draw water from the forebay and pass that water to the tailrace. These fishways are the adult fishway and the juvenile fish bypass system. At some projects on the Columbia River there have been documented instances where the water in the adult fishway has been shown to increase in temperature during transit through the fishway. In other instances, the structures that draw water into either an adult or a juvenile fishway have withdrawn surface waters that are warmer than the predominant water temperature in the forebay of the project. Although the quantity of flow in fishways is too small to have a significant warming effect on water temperatures in the Columbia River, the fishways have the potential to increase the exposure of salmonids and other cold-water fish to harmful warm water temperatures. In fact, fish mortality has been observed at McNary Dam, where warm surface waters were concentrated in the juvenile fish bypass system and turbine intake gatewells.

The Rocky Reach adult fishway is comprised of a fish exit, a fish ladder (which contains 67 cfs of flow), a lower fishway (comprised of a transportation, tunnel, and collection channels and bi/trifurcation pool), and three entrances and an associated attraction water system (Figure 27). A total of four sources of water, including both gravity-fed and pumped components provide water to the system (Table 8). These include two inflows from the forebay to the ladder that provide water to the ladder and two inflows to the lower fishway that act as attraction water sources for each of the three entrances

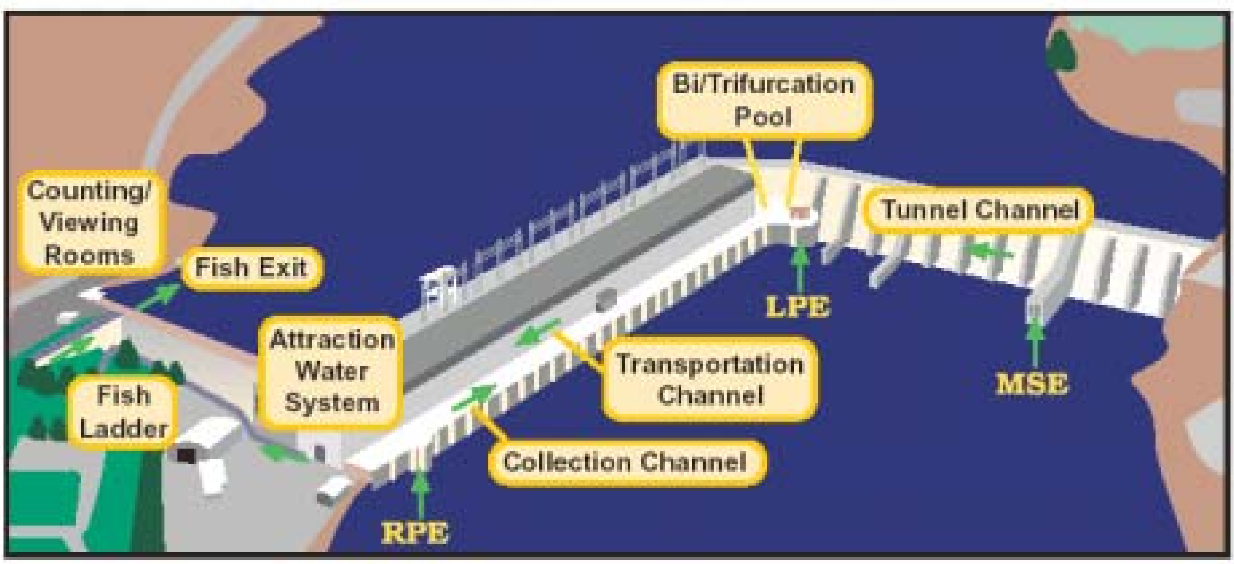


Figure 27: Adult Fishway System

Note: (RPE = right powerhouse entrance, LPE = left powerhouse entrance, MSE = main spillway entrance).

Table 8: Adult Fishway Water Sources

Source of Water	Location of Input in System	Depth of Withdrawal	Quantity of Water
Gravity-fed from forebay, directly	Top of fish ladder at exit	Evenly from surface to depth of 13 feet when forebay full	About 60% of 67 cfs, or up to 40 cfs; when forebay is full
Gravity-fed from forebay conduit	Upper end of fish ladder at first overflow weir	Evenly from surface to depth of 57 feet from bypass system pump station	About 40% of 67 cfs, or 27 cfs; when forebay is full
Pumped from the tailrace	Throughout transportation and collection channels	Majority from the tailrace, approximately 10% from surface to 25 feet when forebay full	Up to 375 cfs from forebay, 3900 cfs from tailrace
Gravity-fed from spillway between bays 8 and 9	Upstream from spillway entrance	20 feet of depth when forebay full	75-150 cfs of attraction flow

At the upper end of the fishway at the forebay (the exit from the fish's point of view), flow enters the fish ladder via gravity flow, both directly from the forebay into the fishway exit and additional water that is withdrawn from the forebay through a conduit and introduced to regulate flow levels at the pool-and-weir (ladder) section of the fishway. The pool and weir section, which is above the lower fishway, has a flow of 67 cfs, which is held constant by holding a head differential of 1.0-1.2 feet over each weir. Water entering through the fishway exit is evenly distributed from the water surface to the floor of the fishway exit at elevation 694, a depth of 13 feet below maximum forebay elevation of 707. The volume of flow entering by this route is variable, depending on forebay elevation. When the forebay is full, at elevation 707, the flow entering from the fishway exit is about 60% of the fishway flow. The remaining flow (make-up water) is provided from the conduit, which measures 6 feet high by 4 feet wide, with its centerline at elevation 692.5. This make-up water is thus drawn from a depth of about 12 to 17 feet below the forebay water surface. Prior to construction of the juvenile fish bypass system (completed in 2003), the development of a warm surface layer would have been undisturbed by turbulence. Since 2003, the water discharged from the juvenile fish bypass system pump station mixes with the forebay water, introducing water drawn from the forebay at depths up to 57 feet. The make-up water conduit is now supplied from water discharged from the bypass system pump station.

Water is supplied to the lower fishway in two locations, one pumped and the other through a gravity-fed intake. The gravity-fed intake, located at the spillway between bays 8 and 9, is used to supply 75-150 cfs or more, depending on tailwater elevation, of attraction flows to the spillway entrance. This intake is located at an elevation of 687, or approximately 20 feet below the full forebay elevation.

The pumped water is the main source of attraction water for the powerhouse fishway entrances. It is provided by three direct-drive turbine pumps, which can each withdraw up to 1,300 cfs from the tailrace near the south end of the powerhouse. Three forebay intakes provide 125 cfs flow, required to drive turbine pumps, which is drawn from the forebay through an intake that extends from the water surface to a depth of 25 feet. That intake is provided with traveling water screens to prevent the entrainment of fish.

Water temperatures within the adult fishway were recorded hourly with five probes at each of four locations from May 29 to October 19, 2001 and with eight probes at each of seven locations from August 19 to October 7, 2004 (two depths were monitored at one location; see Figure 28). During the low flow year of 2001, fishway water temperatures would be more likely to demonstrate any tendency to either collect warm water from stratified surface layers or warming within the fishway than would be likely during years with higher river flows. The collection of warm water is the withdrawal from a localized warmer area as opposed to a uniform draw over a mixed flow. During the high ambient air temperature of 2004, the net heat available to increase the water temperature is greater than in cooler years.

In 2001 the temperatures were recorded within the fishway in the source water at the exit at shallow depth (108 inches from the bottom), the exit at deep depth (16 inches from the bottom), in the third pool downstream of the make-up water (22 inches from the bottom), at the beginning of the diffusion pools (42 inches from the bottom) and in the trifurcation pool (84 inches from the bottom). These measurements show if any warm water was collected from the forebay (represented by the exit locations) and whether the water warmed during transit through the pool and weir section of the fishway. In 2004, the same locations were monitoring but four additional locations were added including: at the powerhouse entrance, within the transportation channel at the right powerhouse entrance, in the middle of the transportation channel, at the left powerhouse entrance and at the spillway entrance. Each of these locations was monitored at a depth of six and one-half to eight feet from the bottom.

The pool and weir section is the only part of the fishway exposed to solar warming. Water temperatures were also recorded at the trifurcation pool, where attraction water pumped from the tailrace makes up the majority of the fishway flow. The difference in temperatures between measurement points averaged less than 0.1°C between comparisons of each pair of measurement locations. The maximum difference in any comparison was less than 0.5°C for all locations within the 67 cfs ladder flow. The maximum difference between the trifurcation pool location and the 67 cfs portion of the fishway was 1.0°C for one hourly reading on July 12, 2001, and 0.4°C on several days in 2004. However, the water temperature in the 67 cfs portion of the fishway was typically within 0.1°C of the temperature at the trifurcation pool, which was supplied with thoroughly mixed water discharged from the turbines into the tailrace.

The average water temperature in the adult fishway during the 2001 study was 16.5°C at all locations and the maximum temperature, 19.3°C on September 23, was also recorded to be within 0.1°C at all locations. The average water temperature in the adult fishway during the 2004 study (limited to the hot months of August and September) was 19.2°C at all locations and the maximum temperature, 20.3°C on each five days, was recorded to be within 0.3°C at all locations. These differences in water temperature measurements are less than the precision of the temperature recording devices, thus there was no measurable difference in temperature between any locations, just measurement error. The findings of a statistical evaluation using matched pairs are presented in Table 9 and Table 10 for 2001 and 2004, respectively. In 2001, the exit locations represent any surface warming that might have occurred in the forebay. In 2004, after the installation of a surface collector that introduces vertically mixed forebay water to the fishway exit, the downstream data represents the Columbia River. No significant differences are noted. This evidence demonstrates that there is no significant difference in water temperatures within the adult fishway and no evidence that the fishway concentrates warmer surface waters from the forebay. There is no evidence that shielding the pool and weir section of the fishway from solar radiation would have any beneficial effect of reducing water temperatures in the fishway.

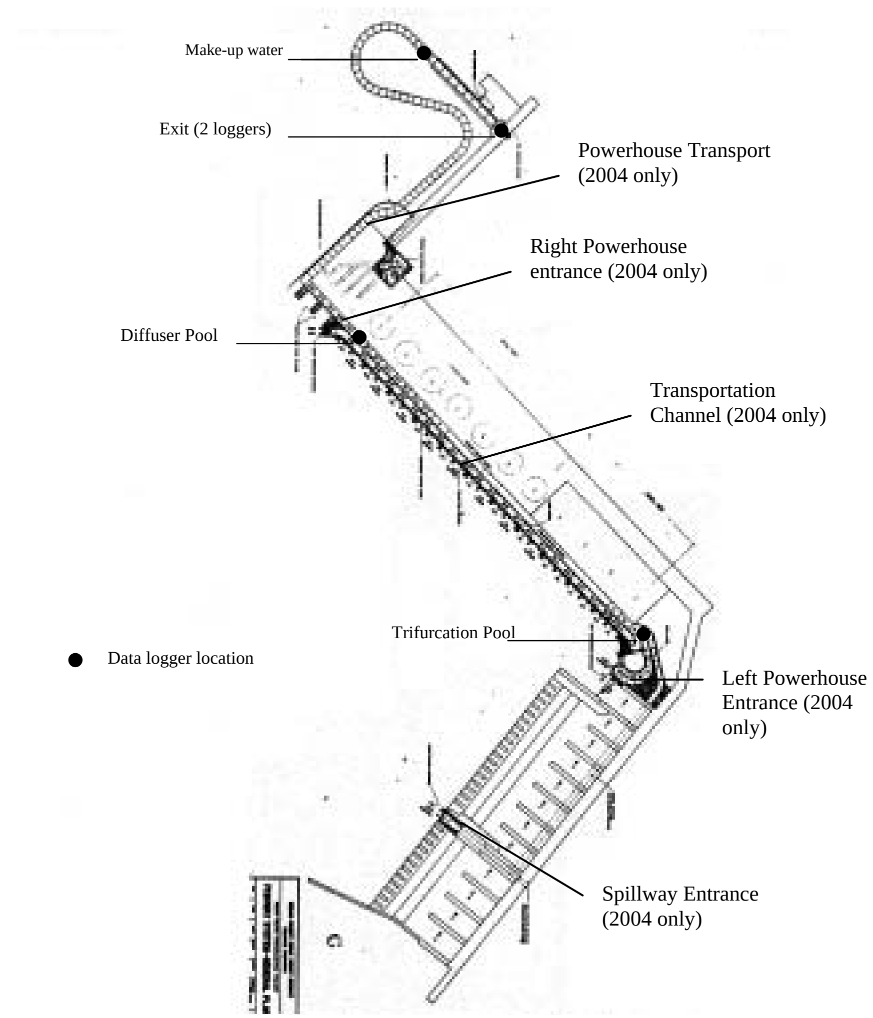


Figure 28: Fishway Temperature Monitoring Locations

Table 9: Mean 2001 Fishway Temperatures and Probabilities of Similarity

Monitoring Locations	Mean Temp. (degrees C)	T-test Probability Value*				
		Exit Shallow	Exit Deep	Makeup	Trifurcuration	Diffuser
Exit Shallow	16.5	----	0.9995	0.99934	0.99884	0.99905
Exit Deep	16.6	----	----	0.99917	0.99894	0.99906
Makeup	16.5	----	----	----	0.99867	0.99909
Trifurcuration	16.4	----	----	----	----	0.9988
Diffuser	16.5	----	----	----	----	----

Note: The accuracy of the measuring equipment is 0.2°C.

* A value of one means the two sets are identical.

Table 10: Mean 2004 Fishway Temperatures and Probabilities of Similarity

Monitoring Location	Mean	T-test Probability									
		Down Stream	Exit Deep	Exit Shallow	Makeup Water	Transportation Channel	Trifurcation Pool	Powerhouse Transport	Powerhouse Entrance	Middle Entrance	Spillway Entrance
Down Stream*	19.2	---	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Exit Deep	19.1	---	---	0.97	0.98	0.95	0.97	0.99	0.96	0.98	0.96
Exit Shallow	19.1	---	---	---	0.95	0.95	0.95	0.97	0.99	0.95	0.95
Makeup Water	19.2	---	---	---	---	0.95	0.98	0.98	0.95	0.99	0.97
Transportation Channel	19.2	---	---	---	---	---	0.95	0.95	0.96	0.95	0.96
Trifurcation Pool	19.1	---	---	---	---	---	---	0.97	0.95	0.99	0.97
Powerhouse Transport	19.1	---	---	---	---	---	---	---	0.96	0.98	0.96
Right Powerhouse Entrance	19.1	---	---	---	---	---	---	---	---	0.95	0.95
Left Powerhouse Entrance	19.2	---	---	---	---	---	---	---	---	---	0.97
Spillway Entrance	19.2	---	---	---	---	---	---	---	---	---	---

* Downstream represents the Columbia River, not flow in the Fishway.

The juvenile fish bypass system draws water from two different structures, the surface collector and turbine intake gate slots. The surface collector draws 6,000 cfs into two entrances that are each 20 feet wide and 57 feet deep. A majority of the flow entering the surface collector is drawn off through screen panels and returned to the forebay by pumps, with 240 cfs flowing over two weir gates and into the bypass pipe. The water flowing over the weir gates is somewhat mixed, but likely predominately originating from the surface waters entering the surface collector from the forebay (in the upper 57 feet). The weir gates operate with a submergence averaging two feet below the water surface. In addition to the 240 cfs from the surface collector, the turbine intake screen and gatewell collection system adds 120 cfs to the bypass pipe. The flow in the turbine intake gatewells comes from the water drawn into the upper portion of the turbine intake, which comes from a depth of 70-90 feet deep in the forebay. The gate slots at the Project are narrow and the water residence time is very short, thus there is no potential for exposure of fish to warm surface waters concentrated in the gatewells, such as has been reported at McNary Dam.

The water in the juvenile fish bypass system is not warmer than ambient water temperatures in the Columbia River and it does not increase in temperature during transit, which takes approximately six to eight minutes. Water in the bypass pipe is largely shielded from solar radiation and warming from exposure to warm air because the pipe provides shade, there is some evaporative cooling within the pipe and the water flows through the pipe very rapidly. Although the 240 cfs entering from the surface collector is primarily from the surface of the forebay (the upper five feet), the pump station discharge mixes the 5,760 cfs from the lower depths (57 to 62 feet) that enters the surface collector with the forebay surface waters, thus preventing even short periods of near-surface thermal differentials in the forebay. Additional research to definitively describe the thermal conditions is ongoing.

3.2.2.3 Cooling Towers

Cooling towers use the process of evaporation, whereby the heat of vaporization (a means of removing heat) cools the water remaining in the liquid phase to a lower temperature. Cooling towers fall into two major types, natural draft and mechanical draft. Natural draft designs use very large concrete chimneys to introduce air into contact with falling water, whereas mechanical draft designs use large fans to force air through circulated water. Natural draft towers, typical of many nuclear and other thermal power plants, are very large (for example, 500 feet high and 400 feet in diameter at the base) and are generally used for water flow rates above 200,000 gallons per minute. This type of tower is often a counter-current design. In counter-current cooling towers the liquid water stream is introduced at the top of the tower and falls over packing material and is exposed to air that is flowing upward through the tower. Once in contact, the water at the gas-liquid interface evaporates into the air stream. Latent heat of evaporation is carried into the bulk air by the water vapor. Thus, the temperature of the water is lowered. Therefore, the water flow rate and the water temperature decrease as the humidity of the air increases from evaporation. This process also known as humidification involves the simultaneous transfer of mass and heat.

There are many factors that contribute to the design of cooling towers, but for the purpose of reducing water temperatures in the Columbia River there are three critical factors that determine the feasibility of cooling tower technology. These key factors are the desired water temperature, the difference between the desired water temperature and incoming water temperature, and the difference between desired water temperature and the heat content of ambient air. The heat content of ambient air (in effect the cooling capability of the air) is indexed by the typical wet bulb temperature of the air. In cooling tower design, the wet bulb temperature of the air must be lower than the desired water temperature to cool the water. This difference between the desired cool water temperature achieved and typical wet bulb temperature is called the approach.. Cooling tower size requirement varies inversely with approach, thus a smaller approach requires a larger tower and, at 5°F (2.8°C) approach, the effect upon tower size begins to become asymptotic (Figure 29). In other words, if the wet bulb temperature is, for example 60°F (15.6°C), the coolest the water can be coming from the cooling tower is 65°F (18.4°C). Thus, for cooling towers to be a feasible technology for a desired water temperature, the difference between the desired water temperature and the ambient wet bulb temperature must be greater than 5°F (2.8°C).

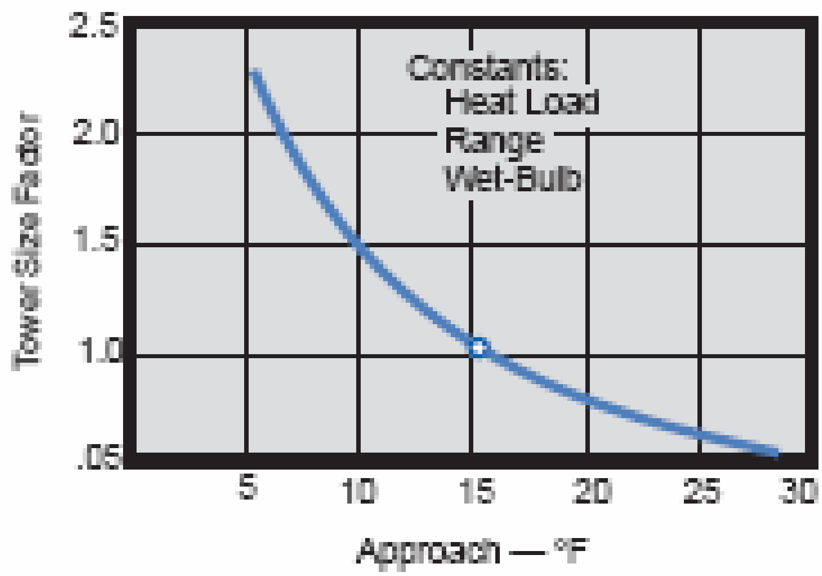


Figure 29: Relationship between Cooling Tower Size and Approach Temperature

There are two conceptual applications for use of cooling technology to mitigate the effects of water temperature on aquatic species at the Project. One concept would be to build a massive cooling tower to reduce the temperature of Columbia River water to mitigate for temperature increases resulting from existence of the reservoir. This cooler water could then be returned to the Columbia River as either a mixing discharge or as a cool water plume intended to provide a cool water refugium. Another concept is to use a smaller cooling tower to reduce the water temperature in the fishway for upstream migrant salmon and other fish. Both concepts would be employed in the summer months, when water temperatures in the Columbia River reach 18°C (64.4°F). The desired cool water temperature would be something cooler than 18°C, for example 16°C (60.8°F). Thus, for cooling tower technology to be feasible for this application, the approach must be at least 5°F and therefore the wet bulb temperature of ambient air must be less than 56°F to achieve a cool water result of 16°C. In typical design of cooling systems, the tower is built to meet the desired objective most of the time, defined as the percentage of the time a given temperature doesn't provide adequate cooling. The wet bulb temperatures are typically reported at 0.1, 0.5, and 2% levels, corresponding to temperatures in above the reported value 9, 44, and 175 hours of the year, respectively. The lower the percentage, the higher the wet bulb temperature reported. The American Society of Heating, Refrigeration and Air Conditioning Engineers has published design data for Washington State and they report the 2% wet bulb exceedance for Wenatchee to be 64°F (17.8°C) during the summer (Puget Sound Chapter of the American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., 1986). In effect, the water sent through a cooling tower could not effectively be cooled below 69°F (20.6°C) during 175 hours of the year.

Data recorded at the USDA Forest Service weather station at Entiat show that the daily mean wet bulb temperature during July-August is frequently above 56°F (13.3°C; Figure 30), thus a cooling tower would frequently fail to provide significant cooling of water during these summer months (given that at an approach of 5°F, the water couldn't be expected to be cooled below 61°F or 16.1°F). Even cooling of fishway water temperatures would be infeasible because the wet bulb temperature is often so high that little, if any, cooling of water would occur during the months of July-August.

Even if the approach temperature was within the feasible range for cooling tower technology, there are other reasons why cooling towers are not a feasible means to reduce water temperatures in the Columbia River. First, there is the massive quantity of water that needs to be cooled. Assuming an average Columbia River flow of 100,000 cfs, the number of British Thermal Units (BTU) of cooling capacity needed to reduce the water temperature by 0.3°C (the allowable human effect in the water quality standards) is approximately 202 million BTU per minute. Most of the heat reduction in a cooling tower is due to evaporation, with approximately one pound of water evaporated for every 1,000 BTU of heat removed from the remaining water. Thus, to cool the Columbia River by 0.3°C, the consumptive use of water lost to evaporation would be approximately 202,000 pounds of water per minute, which is equivalent to 107 acre-feet per day. Assuming the cooling tower was operated from July-September, approximately 90 days per year, the annual consumption of Columbia River water would be 9,640 acre-feet. This estimate is conservative because it does not account for water loss from blowdown and windage. Blowdown wastewater needed to clean media, the internal components of the tower, is both a water loss and a potential disposal issue. Another water loss results from windage or drift. Windage is the loss of water, as droplets, carried away by the air flow (not adequately represented by the humidity calculations). Windage loss is typically in the 0.1% to 0.3% range for mechanical draft towers

The water loss from a cooling tower would be equivalent to approximately one third of the future consumption allowed in a water withdrawal permit issued by WDOE to the Quad Cities (Richland, Kennewick, Pasco and West Richland) in November 2002. Due to concerns about the potential effects of reduced Columbia River flows on migrating salmon and steelhead, WDOE required mitigation for this municipal water allocation in the form of conservation and acquisition and transfer of other water rights. It would make little sense to attempt to reduce water temperatures in the Columbia River with technology that creates a consumptive use of water that rivals major metropolitan water use, and further, reduces river flows downstream which leads to increased heat uptake and temperature increases in the downstream reaches of the river.

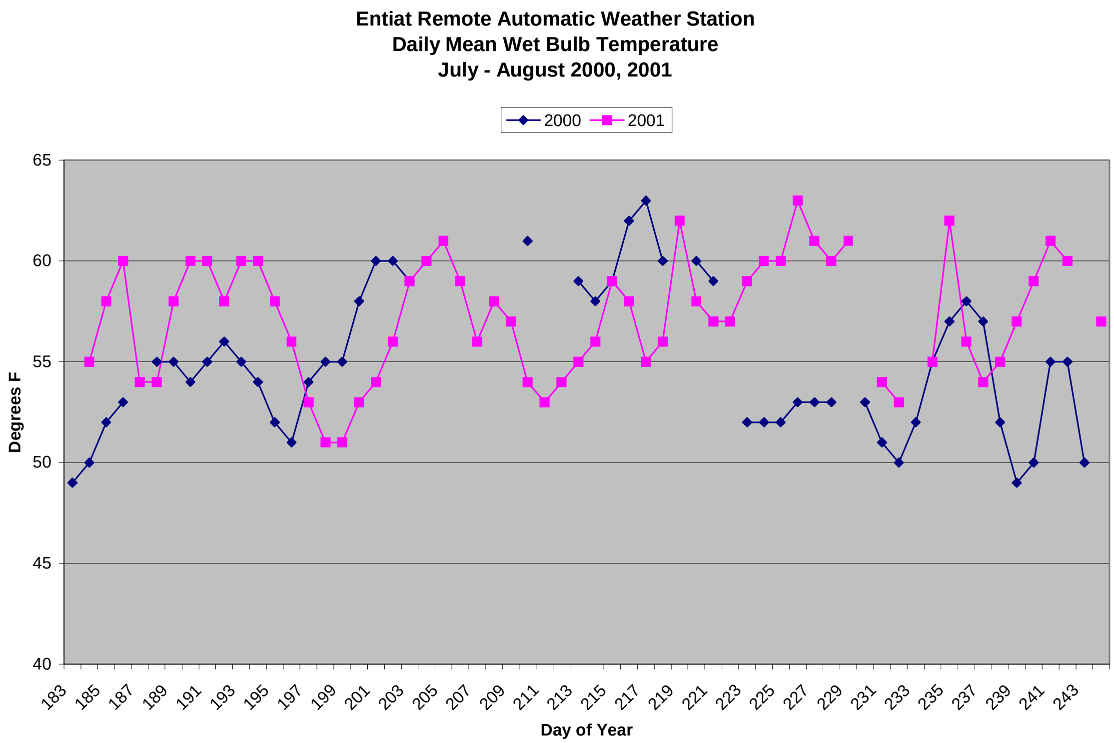


Figure 30: Daily Mean Wet Bulb Temperature at Entiat Remote Automatic Weather Station, July to August, 2000, 2001

3.2.2.4 <u>Chillers</u>

Chillers use the process of refrigeration to transfer heat from a low-temperature area to a high-temperature area. In a refrigeration cycle, work is the input to get the desired cooling effect. Since heat flows naturally only from high- to low-temperature areas, refrigeration needs an external energy source to force heat transfer to occur. This energy source is a pump or compressor that does work in compressing the refrigerant. It is necessary to perform this work in order to get the system to discharge energy (heat) to the high temperature area. Refrigerants are the transport fluids which convey the heat energy from the low-temperature area to the high-temperature area.

General refrigeration devices consist of a coil (the evaporator) that absorbs heat from the low-temperature area, a condenser that rejects heat to the high-temperature area, a compressor, and a pressure reduction device (the expansion valve or throttling valve). In operation, liquid refrigerant passes through the evaporator where it picks up heat from the low-temperature area and vaporizes. The vaporized refrigerant is compressed by the compressor and, in so doing, increases even more in temperature. The high-pressure, high-temperature refrigerant passes through the condenser coils, and being hotter than the high-temperature environment, loses energy (heat). Finally, the pressure is reduced in the expansion valve, where some of the liquid refrigerant also flashes into vapor further reducing the temperature of the refrigerant.

There are many factors that must be evaluated in the design of a chiller. Two key aspects of the design are the refrigerant used and the method of applying the refrigeration to the area to be cooled. The refrigerant used depends on the temperatures of the low- and high-temperature area, as well as on the power of the compressor. There are environmental impacts associated with the use of most refrigerants. Although there are more than a hundred commercial refrigerants commonly available, fluorinated hydrocarbons (e.g., freon or chlorofluorocarbon [CFC] chemicals) are currently used (at least where they are not banned) for most commercial applications. Recent evidence indicates that much of the damage to the atmospheric ozone layer is the result of decomposition of CFC chemicals. An international agreement known as the Montreal Protocol took effect in 1989 and a new Clean Air Act was signed into law in 1990 to limit the production and regulate the use and disposal of CFCs. Prior to the Montreal Protocol, refrigerants R-11, R-12 and R-22, in pure form or blends, were the traditional choices for most systems. Chiller designs historically use R-11 which is now being replaced by hydrochlorofluorocarbon (HCFC)-123 a refrigerant that has a much lower ozone-depleting effect. In contrast, the toxicity limit of HCFC-123 is much lower than the original R-11 refrigerant (meaning that risk from exposure is encountered at lower levels of concentration).

The method of applying refrigeration is another matter to consider. In direct expansion systems the evaporator is placed in the area which is to be cooled. In indirect systems a secondary fluid (brine) is cooled by contact with the evaporator surface, and the cooled brine goes to the region which is to be refrigerated. Brine systems require 40 to 60% more surface area than do direct expansion. Brine systems are safer for systems where the refrigerant effect must be carried considerable distance or widely distributed. Due to safety concerns, direct expansion systems are not feasible for this application. Brines used for industrial refrigeration are usually aqueous solutions of calcium chloride, ethylene glycol, propylene glycol or undiluted methylene chloride and silica-based alkylated fluids. Corrosion by brine is increased by the presence of oxygen, air or carbon dioxide and by galvanic reaction between dissimilar metals. Corrosion inhibiters can be used to offset this affect to some extent.

The application of chiller technology to cool the temperature of the Columbia River water has some potential pitfalls due to the enormous cooling load required. Using the same calculations as for cooling towers, cooling a river flow of 100,000 cfs by 0.3°C requires a cooling capacity of 202 million BTU per minute. Refrigeration capacity is defined in terms of the "ton", where a ton of refrigeration is equal to 200 BTU per minute (which is roughly the equivalent amount of heat to melt a ton of ice in one day). Therefore, chillers would need to be sized to provide approximately 1,010,000 tons of refrigeration. To place this in perspective a typical household will require 1 to 5 tons of refrigeration or a multi-story office building can require from 500 to 2,000 tons of refrigeration. Thus in a best case, the cooling load is equivalent to about 500 large multi-story office buildings. The refrigeration plant would likely be equivalent in scale to the existing powerhouse and require a cooling tower to reject the heat load from the cooling system. The heat load would be equivalent to the cooling tower scenario with the addition of the heat generated from the compressors and all the associated problems discussed in the cooling tower section.

Another issue centers on the heat exchange between the chiller system and the river water. As discussed previously a brine system (indirect expansion) would limit the potential of refrigerant leaks directly to the river and provide the best means to distribute over a large area. The brine system is a secondary loop between the river water and the chiller systems. The heat exchange can then be applied by either drawing off a percentage of the river and passing it through a heat exchanger or by employing banks of tubing immersed directly in the river. If a heat exchanger is used only a small percentage of the flow can be directly treated, due to the need to filter out the large particulate from the river water, then the treated water would be mixed back into the river flow in some manner. This approach would also require fish screening of the intake. The other option is to use banks of piping immersed directly into the river. Either application is very similar to a double pipe cooler which typically requires 15 to 20 feet of two-inch pipe for each ton of refrigeration needed. Using the minimum of 15 feet of pipe, this translates to approximately 15 million feet of two-inch pipe needed to transfer the heat from the river to the brine system.

There are no other known suitable technologies for directly cooling the reservoir or powerhouse discharge. The alternative approach is to prevent heat from entering the river by altering the heat transfer dynamics of the river. Wind towers could be placed in numerous locations along the reservoir and directed at the water, thus increasing evaporation and reducing water temperatures. The CE-QUAL-W2 has a wind sheltering coefficient, which is a factor that the measured wind must be multiplied to help calibrate the wind speed input value. By varying this coefficient and observing the effect, it is possible to determine how much wind is necessary to cool the water. In a sensitivity analysis of the effect of wind levels on water temperatures (personal communication, Todd Bennett, WEST Consultants, 2005), the wind sheltering coefficient of the CE-QUAL-W2 temperature model had to be set to a multiplier of two to create a measurable change in the surface water temperatures. This implies that wind twice that of normal, or up to 20 meters per second, would likely be necessary to cool the Columbia River by a measurable amount.. It is unlikely that wind towers could replicate the level of additional wind that would be necessary.

3.2.3 Other Options Considered to Limit Heating of the Reservoir

Increased shade through establishment of riparian vegetation, especially trees, along the shoreline is often the focus of actions to control water temperatures on smaller streams. In the case of the Project, the amount of shade that could be provided from shoreline vegetation is insignificant in relationship to the total amount of reservoir surface exposed to solar radiation. The Rocky Reach reservoir is typically more than 1,000 feet wide in the narrow sections and from 2,000-3,000 feet wide in the broad sections. Even when directly aligned with the sun's position for maximum shade, a 100-foot tall tree, planted right at the waters edge, will project a shadow of only about 45 feet during the middle of the day in August. Thus, even if the shoreline was thickly planted with tall cottonwood and pine trees, there would be no measurable reduction in water temperatures.

As mentioned in the previous sections, increased wind, decreased humidity, increased cloud cover and other climatic factors affect water temperatures. However, there are no practical methods available to modify these factors. The rate of flow in the Columbia River does influence the water temperature, at least as far as the amount of heat uptake that occurs within a single reservoir. However, as previously discussed (Section 3.2.1.1), the Project does not have sufficient useable storage to change river flows on a daily and weekly basis. The use of storage from Grand Coulee Dam to modify flow rates during the summer is already being done under the FCRPS Biological Opinion. The management of the FCRPS for improvement of water quality, including temperature, is being addressed in the implementation of the FCRPS Biological Opinion. Summary of Project Effects and Mitigation Options

The CE-QUAL-W2 modeling of years 2000 through 2004, which includes worst case years, did not yield any simulated impacts that were statistically greater than the allowable incremental temperature increases for human effect under the 1997 water quality criteria. The largest simulated Project impact during the summer months (defined as when the simulated background water temperature was 17.7°C or higher) was approximately 0.7°C. In no case was the simulated project impact, when calculated using the proposed water quality criteria, greater than the allowable increment. The overall Project impact on water temperature, therefore, appears to be quite small. The ability to measure the water temperature more accurately (the current instrument provide an accuracy of 0.2°C) is required before it would be possible to determine if any potential mitigation option is effective once implemented.

The above review explored a broad range of conceivable methods and technologies for reducing water temperatures or limiting uptake of heat from solar and atmospheric sources that were potentially within control of the Project. None of these methods would produce a measurable effect or were technically feasible. The amount of temperature increase resulting from the existence of the Project is related to the river flow, but that potential means to lower temperatures is not within the Project's control. The fish species most sensitive to water temperatures are migrating adult salmon, which during the warmest summer months are seeking entry into the tributary streams where they spawn. These tributary streams (Entiat, Methow and Okanogan rivers) all have elevated water temperatures in the summer. In fact, the water temperature in these streams often exceeds the water temperature in the Rocky Reach reservoir. Under these conditions, salmon may delay entry into the tributaries and use the Columbia River as a thermal refuge. The tributary streams are small enough to accomplish some temperature reductions through increased shade from riparian vegetation and improved streamflows during the hot weather from July to September. Chelan PUD has provided funding for improvement in tributary habitat under the HCP and typically these habitat improvements include components that improve water temperature. Typical habitat improvement measures that also improve water temperatures include restoration of shoreline riparian habitat, restoration of floodplain and side channel connectivity, and increases in instream flows through water conservation, water rights leases and other measures. All three of the tributary streams have ongoing watershed planning and improvement efforts which will eventually result in reduced water temperatures and improved access to these streams by adult salmon migrants. The Chelan PUD funded HCP tributary projects will contribute to these water temperature reductions in the tributaries.

SECTION 4: PROTECTION, MITIGATION AND ENHANCEMENT MEASURES

4.1 Total Dissolved Gas Management

4.1.1 Current Operations

Chelan PUD currently manages TDG and fish spill in accordance with a Gas Abatement Schedule for Compliance, which Chelan PUD has voluntarily submitted to WDOE. The most recent schedule was submitted in February of 2004 and was accepted by WDOE for a one-year period. The 2004 schedule ~~(Appendix D)~~ was submitted as a five-year plan. As components of this schedule for compliance, Chelan PUD monitors TDG levels at two fixed monitoring sites, one in the forebay and one downstream from the Project. Chelan PUD also participates in a cooperative program to monitor biological response of salmonids to TDG levels.

Data is transmitted on a daily basis to various web-accessible databases used by WDOE and regional fish management agencies. Chelan PUD uses the monitoring data and study results to set spill patterns and manage spill volumes to meet the dual objectives of improving fish passage survival and minimizing TDG levels. Rocky Reach operations personnel follow the Rocky Reach Operational Plan for TDG ~~(Appendix D)~~ to respond in real-time to TDG monitoring information in order to prevent exceedances of the TDG levels allowed under WDOE's water quality standards.

The current Rocky Reach Operational Plan is summarized herein. If necessary, this plan may be modified by Chelan PUD in consultation with WDOE. Under the Operational Plan, if the TDG level in the tailrace is at or above 120% for a six-hour average, or above 125% for one hour, the spill is reduced by 3 kcfs and monitored for an hour. If the TDG level is not reduced below 120% over the next six-hour average, the spill is reduced by another 2 kcfs and monitored for an hour. The cycle continues, with the spill reduced by 2 kcfs as needed until the TDG level is less than 120% for one full hour. If the TDG then drops below 118% for one full hour, the spill is increased by 2 kcfs and monitored. If the TDG in the forebay of Rock Island exceeds 115%, the personnel notify Rocky Reach immediately. If Rock Island calls Rocky Reach to notify them that the TDG level in the Rock Island forebay is greater than 115% and the forebay of Rocky Reach is less than 115% the spill is reduced by 3 kcfs and monitored for two hours. If the TDG levels are still above 115%, the spill is reduced another 2 kcfs. If, after reducing spill, the TDG level in the forebay of Rock Island is less than 113%, Rock Island will notify Rocky Reach that they may increase spill slightly. Rocky Reach will increase spill to the level believed necessary to comply with the TDG level of 115%.

In addition, Chelan PUD has completed actions and investigations specified in the Gas Abatement Schedule for Compliance, which include issuance of final reports on TDG Exchange (COE, 2003) and TDG Biological Effects on non-salmonid fish and macroinvertebrates (Parametrix and RL&L, 2003), completion of a review of gas abatement technologies that may be applicable to the Rocky Reach Hydroelectric Project (MWH, 2003), and completion of a juvenile fish bypass system that has reduced the need for spill as a fish passage measure.

Chelan PUD's commitment in the Gas Abatement Schedule for Compliance is to make best efforts to meet the TDG criteria during each fish migration season. Chelan PUDs long-term goal is to minimize the frequency and magnitude of spill, and resultant TDG, needed to increase fish survival, consistent with meeting HCP fish survival objectives. Studies completed in 2003 on the fish bypass system's efficiency resulted in a reduction in the amount of spill used in 2004 to meet the survival objectives of the HCP. The long-term level of spill necessary to meet HCP fish passage survival objectives is scheduled to be determined after completion of three to four years of survival studies that were initiated in 2004. Once the volume and timing of voluntary spill necessary for fish passage survival has been determined, Chelan PUD has committed to implement operational measures necessary to meet TDG criteria and protect aquatic life. Chelan PUD proposes to- monitoring fish populations to determine if TDG levels are causing harm to aquatic life. The results of these studies will be provided to DOE and EPA for their review. Chelan PUD is committed to implementing additional reasonable and feasible structural measures to further reduce TDG, if monitoring results show aquatic life is harmed by TDG entrainment resulting from operation of the Rocky Reach Project. Chelan PUD intends to fulfill these commitments under the new license, 401 Certification and Comprehensive Plan Section 4.1.3.

4.1.2 Recent Spill Reduction

Chelan PUD has implemented operational improvements that reduce spill, both during the fish migration season (April-August) and during the September to March period, when the criterion of a TDG level of 110% is in effect. The track record for TDG abatement by reducing spill through operational measures at the Project has shown continuous improvement over the past five years. In response to requests from WDOE, Chelan PUD has prepared summaries of the incidence of spill since 1995 (Table 11 and Table 12). Flows prior to 1995 are not included because operations of upstream storage projects were modified by the FCRPS 1995 Biological Opinion. These tables show that flows arriving at the Project will rarely exceed the hydraulic capacity of the powerhouse during the September-March period. Also, even low levels of spill will cause exceedance of the 110% criterion. Thus, avoidance of spill during this time of year is the most viable means to comply with the water quality standards. During the April-August fish migration season, the Project can comply with 120/115% criteria up to the level of the seven-day, ten-year flow.

During the September to March period, when the TDG special condition for fish passage spill is not in effect at the Project, spill has been very infrequent since 2000. Also, the hourly project discharge has rarely exceeded the hydraulic capacity of the powerhouse since 2000. Hourly total project discharge and spill volumes are shown by month in Appendix E. Three factors have contributed to the reduction in spill and spikes in hourly discharge during these months. The almost complete absence of spill since 2001, other than for fish passage, has been accomplished by 1) implementation of a rigorous planning process that schedules routine maintenance; 2) turbine and generator replacement; and 3) other construction work into time periods when flows are not going to exceed the hydraulic capacity of the available turbine units. Previously, the most frequent and highest volumes of flows that would cause spill were in January to March of 1996. Flows were much higher than normal that year because of major flood events in late December of 1995 and further above normal precipitation through the winter. These spills were also caused by construction activities for the prototype juvenile bypass system that required shutting off several powerhouse turbines while pilings were placed in front of the intakes. This construction activity, because of its magnitude, was a one-time occurrence and future construction will not require extensive powerhouse outages. In fact, construction of the permanent juvenile fish bypass, which included removal of the prototype, was accomplished without similar turbine outages in 2003.

Table 11: Rocky Reach Projected TDG for Flows above Maximum Turbine Flow for Months during the Fish Passage Season, Assuming No Spill Is Being Used for Fish Passage

Spill Level (flow) (Flow-201kcfs)	% TDG	April % of hours	May % of hours	June % of hours	July % of hours	August % of hours
<=10 kcfs (201-211 kcfs)	113.12%	1.91%	2.76%	4.06%	3.36%	0.21%
10 - 20 kcfs (211 - 221 kcfs)	114.63%	1.60%	2.05%	3.72%	2.99%	0.19%
20 - 30 kcfs (221 - 231 kcfs)	116.14%	1.28%	2.11%	2.65%	1.49%	0.03%
30 - 40 kcfs (231 2341 kcfs)	117.65%	0.94%	1.75%	2.36%	0.79%	0.01%
40 - 50 kcfs (241 - 251 kcfs)	119.16%	0.66%	2.18%	2.62%	0.43%	0.00%
> 50 kcfs (>251 kcfs)	NA	0.62%	5.97%	12.47%	0.48%	0.01%
Total Spill Frequency		7.02%	16.82%	27.89%	9.54%	0.46%

TDG is for edge of aerated zone (non-fish spill compliance zone)
TDG estimated from standard spill regression (TDG = 0.1509 x + 111.61)

Table 12: Rocky Reach Projected TDG for Flows above Maximum Turbine Flow for Months Outside of the Fish Passage Season

Spill Level (Flow-201kcfs)	% TDG	September % of hours	October % of hours	November % of hours	December % of hours	January % of hours	February % of hours	March % of hours
10 kcfs (201 - 211 kcfs)	113.12%	0.03%	0.01%	0.00%	0.33%	0.79%	1.57%	1.03%
20 kcfs (211 - 221 kcfs)	114.63%	0.00%	0.00%	0.00%	0.03%	0.39%	0.69%	0.60%
30 kcfs (221 - 231 kcfs)	116.14%	0.00%	0.01%	0.00%	0.03%	0.15%	0.59%	0.37%
40 kcfs (231 - 241 kcfs)	117.65%	0.00%	0.00%	0.00%	0.01%	0.03%	0.64%	0.21%
50 kcfs (241 - 251 kcfs)	119.16%	0.00%	0.00%	0.00%	0.00%	0.01%	0.64%	0.21%
> 50 kcfs (> 251 kcfs)	NA	0.00%	0.00%	0.00%	0.00%	0.01%	0.95%	0.01%
Total Spill Frequency		0.03%	0.03%	0.00%	0.40%	1.39%	5.09%	2.43%

TDG is for edge of aerated zone (non-fish spill compliance zone)
TDG estimated from standard spill regression (TDG = 0.1509 x + 111.61)

4.1.3 Mid-Columbia River and Lake Roosevelt TMDL

The WDOE, jointly with EPA and in cooperation with the Spokane Tribe of Indians, has issued the TMDL for TDG in the mid-Columbia River and Lake Roosevelt. This TMDL sets load allocations to meet Washington State's and tribal water quality standards for TDG for the dams from the Canadian border to the Hanford Reach. The Rocky Reach Hydroelectric Project is one of the seven dams that are included in this TMDL. WDOE has also issued a Summary Implementation Strategy for this TMDL, which incorporated the 2004 Gas Abatement Schedule for Compliance for Rocky Reach as the initial actions scheduled for implementation.

The Summary Implementation Strategy states that a Detailed Implementation Plan for this TMDL will be issued in the future that will refer to the 401 Certification process for PUD projects and update activities at all projects that are improving control of gas generation. The TMDL also establishes load allocations for PUD projects that are equivalent to meeting TDG criteria of 110% during the time of year when fish passage survival is not a consideration (September to March at the Project).

4.1.4 Adaptive Management Plan for TDG Abatement

Chelan PUD will use an adaptive management approach with outcome-based objectives to comply with the Washington State Water Quality Standards for TDG. As previously discussed, the Project currently complies with the 120/115% criteria during the April-August fish passage season. Compliance with the 110% criteria from September to March is based on not spilling water. The outcome of this approach is to protect the aquatic life beneficial uses by meeting HCP survival standards while reducing the incidence and magnitude of spill events, using operations and real-time monitoring at the juvenile bypass system (location FOP1) and in the forebay of Rock Island to manage TDG during spill, monitoring the health of aquatic organisms to assure that no significant harm is resulting from TDG levels that do occur, and if harm to aquatic life is demonstrated, seek additional measures to further reduce TDG levels, as appropriate.

4.1.4.1 Future Reduction in Voluntary Fish Passage Spill

Chelan PUD's preliminary results from HCP survival studies and acoustic tag studies indicate that no spill is necessary to meet the HCP survival standards for yearling Chinook and steelhead migrants. These species migrate from April to mid-June, thus no voluntary spill is expected to be needed during April and early May if the survival studies confirm the 2004 results. Whether voluntary spill will be needed for sockeye and subyearling Chinook will be determined by the end of Phase I of the HCP (2013). Preliminary results in 2004 for these species are not considered reliable at this time due to possible experimental bias from the effects of the tag and other aspects of the study. However, the acoustic tracking study did show that spill may not be an effective tool for meeting the HCP survival standards. Comparison of the relative survivals for the surface collector and the spillway suggest that survival of fish passing through the surface collector is higher. The 24% spill level for sockeye and 9% spill level for subyearling Chinook in 2004 did not have high passage rates for these species. In 2005, a study of sockeye passage and survival, with both a spill and no spill condition, will be used to evaluate the benefits of the 24% spill level and to determine if spill adversely affects fish passage efficiency of the surface collector. Future studies will better define the utility and levels of voluntary spill necessary to meet HCP survival standards for subyearling Chinook.

Voluntary spill levels for 2005 are 0% spill for yearling Chinook and steelhead, 24% spill for sockeye, but with no spill on 12 days during the spill/no spill study, and 9% for subyearling Chinook. These spill levels in 2004 were successfully managed to keep TDG levels well below the water quality standards, with the change in TDG from forebay to tailrace averaging 2.4% (0 to 3.5%), an average tailrace TDG level of 111.4% (109.3 to 113.1%) and Rock Island forebay average TDG level of 111.1% (107.8 to 112.6%). These TDG levels are much lower than the TDG levels produced at the FCRPS projects that are managed to maintain a TDG level just below the 120%.

Chelan PUD will be using acoustic tag study results to increase the fish passage efficiency of the juvenile bypass system, which has thus far shown to produce higher fish survival than the other passage routes at the dam. The long-term goal is to use the juvenile bypass system and other tools, such as predator management, to meet the HCP survival standards. These efforts that lead to reduced use of voluntary spill are the most effective actions that could be taken to reduce TDG levels, as evidenced by the low TDG levels observed in 2004.

4.1.4.2 Minimization of Spill Due to Maintenance

Chelan PUD began an aggressive program in 2000 to limit the incidence of spill due to maintenance outages during periods of the year and times of day when river flows approach the hydraulic capacity of the powerhouse. The hydraulic capacity of the powerhouse, when all 11 turbines are operating, is 201,000 cfs at the most efficient operating point and 206,000 cfs can be passed without needing to spill. Typically, these flow levels are not reached during river management for power generation. The hydraulic capacity of the powerhouse, when 10 turbines are available, is reduced to 189,000 cfs, a flow level that can be reached during periods of peak power demand. The planning process schedules lengthy maintenance outages to the months in the year when flow releases from Grand Coulee and power demand are typically the lowest, with most turbine overhaul scheduled for March to mid-May or September to mid-November. Short duration outages, such as inspections, trash rack cleaning and smaller repair jobs are either scheduled for nighttime and weekends or, if scheduled during the day, are of a nature that work can be suspended or postponed to avoid spill if river flows approach the hydraulic capacity. Outage planning is focused on the shape of the daily flow pattern. The use of the Hourly Coordination Agreement gives the project operations personnel sufficient advance warning to cancel planned outages and avoid spill if the flow pattern changes to higher levels than predicted.

The Project rarely spills for lack of hydraulic capacity (Table 11 and Table 12). The continued improvement in maintenance planning to assure high levels of turbine unit availability during high flow periods is the most effective action that can be taken to prevent unplanned spill and meet the TDG criteria. The Project has not had any incidences of spill between September-March for unit outages or lack of hydraulic capacity since early 2000.

4.1.4.3 Avoidance of Spill Past Unloaded Units (Insufficient Demand for Power)

Under normal operating and flow conditions, water flows and generation requests for Rocky Reach and the other projects under the Hourly Coordination Agreement are managed to prevent spill and meet load demand with the most efficient use of water released from storage. The Hourly Coordination Agreement centralized control of generation requests works well, but it depends on the timely scheduling of load requests by the power purchasers with contractual rights to the mid-Columbia PUD projects. In the past, spill sometimes occurred due to errors or untimely load requests to the coordinated system. The cost (power loss) resulting from this type of spill was originally shared by all the participants. Recent revisions to the Hourly Coordination Agreement now identify the participant whose actions caused the spill and that power loss is deducted from just that participant's account. Spill past unloaded units was uncommon in the past, but this change in the Hourly Coordination Agreement has practically eliminated the incidence of spill past unloaded units. Regional load planning and displacement of higher cost thermal energy sources, such as combustion turbines, has provided markets for energy produced during high flow years and reduced the incidence of spill past unloaded units even when river flows are at or above the hydraulic capacity of the Project.

The types of spill (voluntary fish spill, spill when flows exceed hydraulic capacity (forced spill), and spill past unloaded units) are tabulated and tracked in benchmarking records for the Project. The amount of spill from each category, for the April to August period, has been reported by Chelan PUD in the annual dissolved gas management reports that Chelan PUD has been submitting to WDOE. The April-August spill reported since 2000 has been predominately voluntary spill for fish passage (81%), with forced spill (15%) and spill past unloaded units (4%) being infrequent and low volumes. In 2004, there were only 11 hours of spill that were not fish passage spill (6 in January, 1 in March and 4 on August 31-September 1) and fish passage spill was 99.4% of the total volume of spill for the year.

Spill past unloaded units is infrequent and usually the result of problems with coordination of load requests and movement of water through the coordinated system. The recent improvements in the computer program that implements the Hourly Coordination Agreement and the changes to allocation of the costs of this type of spill will reduce the incidence of spill past unloaded units. The Project has spilled only minimal amounts, less than 0.02% of flow, during the September-March period since early 2000. Continued improvement for efficient operation of the coordinated system is an ongoing priority for operations personnel at Chelan PUD. The results of this effort into the future will continue to reduce the already very low incidence of involuntary spill, resulting in a reduction in the frequency and levels of TDG.

4.1.4.4 Additional TDG Abatement Options

Chelan PUD intends to meet the TDG criteria through the implementation of the measures described above. Past performance and projected future operations indicate that the Project will meet those criteria under ordinary operations. To provide additional insurance that the water quality standards for TDG will be met, a "worst case" analysis was conducted under the assumption that powerhouse capacity was reduced due to an extended outage of one turbine for maintenance during a period of very high flows just below the 7Q10 flow level. This analysis compares the TDG level that would result at the 7Q10 flow (252 kcfs) under current conditions (base), using the standard spill pattern, to TDG levels that are projected to result if additional operational or structural measures were implemented. This analysis (Table 13) shows that the Project is likely to meet criteria without implementation of the additional measures, with the insurance that some additional options could be implemented if necessary to meet the TDG standards.

As previously stated, to be in compliance with TDG criteria during fish spill, the TDG level in the tailrace of Rocky Reach (location FOP1) must be below 120% and the TDG level in the forebay of Rock Island must be below 115%. Historical data indicates that when the TDG level at FOP1 is 120%, the TDG level at the Rock Island forebay averages 115%; therefore, when compliance is met at one location, it is met for both locations. No feasible structural alternatives have been identified that would reduce TDG levels during spill sufficiently to meet the 110% criterion during September – March. Operational measures to maximize powerhouse loading are the only alternatives available.

Maximum Powerhouse Discharge

If necessary to maintain compliance with TDG criteria, which could be slightly exceeded during fish spill if one turbine is down, the flow through the powerhouse could be increased above the peak efficiency curve. When operated under peak efficiency, turbines C1 though C7 will pass up to 17,000 cfs of water and turbines C8 though C11 will pass 21,200 cfs of water, for a total powerhouse flow of 204,000 cfs. The turbine flows can be increased to a total plant volume of 212,000 cfs for several hours, if necessary to control TDG loading (Table 13). To do so would bring the project into compliance at the tailrace for all flows under the 7Q10 flow. During the rare events that flows exceed normal powerhouse capacity during the September – March time period, this same operation could be used in addition to management of active storage to avoid spill.

Spill from Gates 2 Through 12

Only limited testing of this spill configuration was tested in 2002, however that option did show some potential to reduce TDG levels (COE, 2003). The findings from the limited number of test conditions indicated a potential reduction in average TDG levels of up to 2% (Schneider and Wilhelms, 2005).

Entrainment Cutoff Wall

Equations were developed by ERDC (Schneider and Wilhelms, 2005) to estimate the reduction in TDG loading provided by a properly designed entrainment cutoff wall. The TDG in the tailrace will not change with the implementation of an entrainment wall because it only captures spilled water. This alternative has been calculated to reduce the TDG level in the mixed flow at the LD transect by 0.8% to 1.0% (±1.2%) for a small and large turbine being off line, respectively (Table 13). This option would only be needed to meet the 115% criterion for the Rock Island forebay if degassing during water transit through the Rock Island reservoir does not reduce TDG levels sufficiently when TDG criteria are met in the Rocky Reach forebay and tailrace.

Spill Deflectors and Raised Tailrace

ERDC used the TDG exchange relationship developed for Ice harbor Dam to estimate the TDG level in spillway flows for Rocky Reach. This relationship was used to determine the reduction in TDG estimated by the implementation of this alternative in Table 13. Calculations indicate that this alternative would reduce TDG in spill by 4.0 to 4.2 ± 1.2 % when a turbine is down. There remains considerable uncertainty in the estimates of TDG exchange associated with this alternative as applied to Rocky Reach Dam. The interaction of both the continuous baffles and the stilling basin end sill will interfere with the deflected surface jet and may alter the trajectory and TDG exchange properties of this alternative. Extensive hydraulic model studies would be required to develop a design that provides safe stilling action of spill, accommodates the guidance of adult and juvenile salmonids, and effective TDG management. This option would only be needed during high flows and to be effective, the deflectors would need to be designed function under high tailwater conditions. Studies of fish survival at Ice Harbor Dam and other dams with spill deflectors have shown that some deflector installations have decreased the survival of juvenile salmon passing through the spillway when low tailwater conditions were present. Since most spill at Rocky Reach is voluntary spill for fish passage when flow is below 200 kcfs, most spill would occur when tailwater levels are substantially below the design flow for defectors to abate TDG at the 252 kcfs level when they would be most needed. Thus, protection of downstream migrating salmonids may preclude implementation of this option.

Table 13: Rocky Reach TDG Compliance Table

Gas Reduction Scenarios	Estimated date of completion	September - March % of time TDG criterion is met at FOP1		April-August Tailrace criterion: %TDG at FOP1[a]	April-August %TDG at Rocky Reach LD Transect (mixed flow)[a]	April-August Forebay criterion: %TDG at Rock Island Forebay	April-August Instantaneous: %TDG at FOP1[b]~~[a]~~
		Criterion: 110%		***Criterion: 120%***	***Criterion: 120%***	***Criterion: 115%***	***Criterion: 125%***
Base Conditions	Current Operations	Years 1995-1999 93.4% (Lg. down) 95.4% (Sm. down) 94.6% (weight. avg.)	Years 2000-2004 99.5% (Lg. down) 99.6% (Sm. down) 99.6% (weight. avg.)	120.3% (Sm. down) 120.9% (Lg. down)	117.2% (Sm. down) 117.6% (Lg. down)	Averages > 115%	0%
Maximum Powerhouse Discharge	Effective Date of New License	Years 1995-1999 96.1% (Lg. down) 96.7% (Sm. down) 96.4% (weight. avg.)	Years 2000-2004 99.7% (Lg. down) 99.8% (Sm. down) 99.8% (weight. avg.)	119.3% (Sm. down) 119.9% (Lg. down)	116.7% (Sm. down) 117.0% (Lg. down)	Averages < 115%	0%
Spill from Gates 2 through 12	Testing <1 year of high water year	Same as base condition		Unknown, likely around 2% below base.	Unknown, likely around 2% below base.	Unknown, likely slightly lower than base case	0%
Entrainment Cutoff Wall	If TDG and GBT adverse biological effect, <10 years	Same as base condition		Same as base condition 120.3% (Sm. down) 120.9% (Lg. down)	116.4% (Sm. down) 116.6% (Lg. down)	Averages <115%	0%
SD&RTW	TDG and GBT adverse biological effect<15 years	Unknown, likely the same as base condition		116.3% (Sm. down) 116.7% (Lg. down)	115.5% (Sm. down) 115.7% (Lg. down)	< 115%	0%

General Assumptions – Worst Case:

1) 7Q10 flow of 252 kcfs.
2) The highest discharge for base condition within turbine efficiency curve is 204 kcfs. The capacity for the turbines is approximately 17.15 and 21 kcfs for the small (units 1-7) and large (8-11) turbines, respectively. Spill under 7Q10 flow then (calculated by subtracting the missing turbine capacity from the base 204 kcfs and then subtracting that quantity from the 7Q10 flow of 252 kcfs) is 65.2 and 69 kcfs for a small and large turbine down, respectively.

~~2)Base Condition (within turbine efficiency curve) powerhouse flow calculated with one turbine down. This equals the reduction of 17.8kcfs of 204 kcfs (the hydraulic capacity of the Powerhouse on efficiency curve), or 187.0 kcfs capacity with one smaller turbine (units 1-7) down for repair. When one of the larger turbines (units 8-11) out of service, the powerhouse capacity is reduced by 21.85 kcfs to a total capacity of 182.8 kcfs. At 7Q10 flow this provides resultant spills of 252 – 187 = 65 kcfs or 252 – 182.8 = 69.2 kcfs, respectively.~~

3) Maximum Powerhouse discharge is 212 kcfs. The capacity for the turbines is approximately 17.8 and 21.85 kcfs for the small (units 1-7) and large (8-11) turbines, respectively. Spill under 7Q10 flow is 57.8 ~~kcfs~~ and 61.~~85~~9 kcfs for a small and large turbine down, respectively.

~~3)~~For the purpose of the calculations f~~F~~orebay TDG ~~criteria~~ levels never exceeds 110% from September to March ~~are 110%;~~ or 115% from April to August ~~are 115%~~, which match the forebay criteria. ~~.~~

4)

5) FOP1 is monitoring location approximately 1600 feet downstream from the dam, which is consistent with the required TMDL measurement location.

NOTES:

[a]Values are estimated using regressions. The TDG at FOP1 is calculated at 0.1355 times the discharge plus 111.5. The TDG at the LD transect is calculated by multiplying the TDG in the forebay by the volume of water through the powerhouse and adding to the TDG calculated in the spill times the volume of water passed through the spillgates. The TDG at LD transect is calculated by multiplying the flow by 0.1509 and adding 111.61. The values provided have a known error of ±0.6% associated with them due to the error of the regressions used to generate them.

[a]~~Using~~ [b]Using Schneider's regression, 99.6 kcfs of spill are required. This would require 7Q10 flow and 2 turbines down which exceeds worst case assumptions and therefore can be assumed as 0%.

4.1.4.5 Monitoring of Aquatic Life for GBT

Chelan PUD intends to continue evaluation of the biological effects of TDG at the levels allowed in the Washington State Special Condition water quality standards for TDG (120% below dams and 115% in the next dam's forebay). As stated in the lower Snake River TMDL, "probably few river systems have been as extensively studied for the effects of TDG as the Columbia/Snake system. Research has been conducted for over 40 years on TDG and aquatic life. Federal, state, and tribal fishery agencies all support a more lenient standard than currently in state regulation." As part of the adaptive management program for compliance with water quality standards, Chelan PUD will use biological monitoring to assure that the Project's spill operations do not impair aquatic organisms by causing harmful levels of TDG and GBT symptoms.

Monitoring of GBT in salmonid smolts at the Rock Island Bypass Trap sampling site has been conducted for many years. Even though the design of the fish trap and holding facilities and the handling protocol for this sampling program are known to induce GBT symptoms in some fish due the shallow holding tank, the incidence of GBT in salmon smolts in this monitoring program has been very low (section 3.1.2). Chelan PUD proposes to continue to monitor GBT in salmonid smolts at this site and supplement the monitoring with sampling in the Rock Island reservoir to verify that the special condition TDG levels (120% at the Rocky Reach downstream monitoring site and 115% at the Rock Island forebay) do not cause measurable harm to salmonids. Similarly, Chelan PUD proposes to replicate and expand the studies of GBT in non-salmonid resident fish and aquatic macroinvertebrates that were conducted in 2001 and 2002. Those studies (section 3.1.2) demonstrated that these non-salmonid species did not show significant GBT symptoms until TDG levels greatly exceeded the special condition 120%/115% criteria for TDG. The sampling program will use beach seines to capture resident fish and salmonids inhabiting shallow water areas where development of GBT symptoms would be most likely to occur. Macroinvertebrates will be monitored using a combination of grab samples and suspended artificial substrates in shallow water habitats in the Rocky Reach tailrace and downstream locations where TDG levels are most elevated.

Sampling will occur at times that the Project is spilling and causing an increase in the TDG level in the Rock Island reservoir. Sampling will be scheduled to concentrate on times when the TDG levels are approaching or above the 120%/115% criteria at FOP1 and the Rock Island forebay, respectively, to determine if aquatic organisms are adversely affected by TDG levels caused by the Project, which are typically well below the allowable TDG levels. The NOAA Fisheries criteria in the FCRPS biological opinion for the level of GBT symptoms that trigger action to reduce voluntary spill and lower TDG levels are when either 15% of the fish sampled have low level GBT symptoms in the fins or when 5% of the fish sampled show severe symptoms (25% of fish area has bubbles). Since 2000, GBT symptoms have been seen in less than 1% of the fish at the lower Columbia and Snake River sampling sites. At Rock Island Dam, where the extended holding period (up to 24 hours) is known to induce GBT symptoms by exposing fish to shallow water environment for extended lengths of time, the level of GBT in 2003 was 50 fish from a total of 2308 sampled over the season (2.2% of the fish).

Chelan PUD proposes to use the NOAA Fisheries GBT criteria for fish and macroinvertebrates sampled from the Rocky Reach tailrace and Rock Island reservoir as the biological objective for assuring that management of TDG has fully protected aquatic organisms. If GBT criteria are exceeded because of high TDG levels arriving at the Rocky Reach Project from upstream dams, then that exceedance shall not be considered a Rocky Reach Project effect. .

The monitoring data for compliance with the TDG Special Condition (120%/115%), frequency of spill outside the April to August fish passage period, achievement of HCP survival objectives, and the GBT monitoring program for achievement of the biological objective will be analyzed annually to determine of water quality standard compliance has been accomplished. If not, then at the end of the adaptive management period Chelan PUD and WDOE will evaluate whether a second phase of adaptive management is necessary. Phase II of the lower Snake River TMDL is focused on continued implementation of non-spill methods to meet salmon survival standards and continued efforts to minimize spill that is not provided as a fish survival measure. Chelan PUD would seek a similar focus for any second phase implementation strategy. After the measures necessary to maintain the HCP survival standard are defined, Chelan PUD would seek to collaborate with WDOE on an analysis of the water quality standard for TDG from the perspective of attainability and biological necessity. The final determination of compliance with water quality standard for TDG would include evaluation of biological outcomes associated with operational control of TDG. If the operations to control TDG (minimize spill and use of gate sequences that minimize TDG) are shown to not be protective of aquatic organisms, then reasonable and feasible structural measures will be investigated. If there are no additional reasonable and feasible actions to be taken, final actions for compliance may include establishment of a site-specific standard for TDG that protects the biological aquatic resources once reasonable and feasible measures have been thoroughly defined and implemented.

4.2 Adaptive Management Plan for Water Temperature

Water temperature is currently the subject of a TMDL being developed by EPA Region 10. The TMDL will set load allocations for all dams below the Canadian border on the Columbia River. The most recent technical analysis made available by EPA indicated that the Rocky Reach Hydroelectric Project will likely receive a load allocation that is equivalent to the Project's current effects on water temperature. The final load allocation will not be available until the TMDL is completed. The TMDL also will include an implementation strategy for water temperature management that is being developed by WDOE and the federal agencies that control the storage reservoirs which are responsible for most of the water temperature effects. Chelan PUD proposes to continue monitoring water temperature in conjunction with its monitoring program for TDG as its responsibility under the TMDL implementation strategy. Also, the CE-QUAL-W2 model for the Project will be made available to EPA and other entities involved in the TMDL implementation program. Chelan PUD will participate and cooperate with the parties implementing the TMDL. Chelan PUD will also participate in tributary restoration planning and TMDL implementation planning to assure that opportunities to improve water temperature in the tributaries as an adjunct to HCP tributary habitat projects are not lost.

4.3 Project Operations

Chelan PUD will continue to operate the Project in harmony with the other six hydroelectric projects under the Hourly Coordination Agreement. This will result in continued minimization of forebay fluctuations, maintaining a stable reservoir beneficial to aquatic resources, recreation and aesthetics. The Hourly Coordination Agreement also minimizes spill, thus minimizing TDG that could result from spill outside of the fish migration window. Chelan PUD will also operate the Project under the terms of the Hanford Reach Fall Chinook Protection Program Agreement, providing useable storage when needed to supplement flows as provided in this agreement.

4.4 Water Quality in Macrophyte Beds

Macrophyte (aquatic plant) beds are the second most abundant cover type observed in the in the Project's reservoir during aquatic habitat mapping (DES 2001a). At 220,000 cfs flows, cover habitat comprised 16% of the wetted area represented by transects, with boulders accounting for 90% of the cover, with submerged aquatic vegetation and terrestrial grasses providing the remaining cover. At lower flows, only the boulder and aquatic vegetation cover types are available. Macrophyte beds occurred in shallow, near shore environments throughout the length of the reservoir along both shorelines. Large macrophyte beds extended well out from shore in the vicinity of Turtle Rock Island and areas approximately 2.5 miles and about 4.5 miles north of Turtle Rock Island. Large macrophyte beds extend out to mid channel in an area just downstream of Daroga Park. The total area of macrophyte beds in the Project boundary, including pools isolated from the reservoir by highways, was 386 acres in 1999. The most abundant macrophyte species were Eurasian watermilfoil, the dominant species in 30% of the beds, native pondweeds and curly pondweed, in that order (DES 2001a).

Macrophyte beds are important habitat for a variety of fish species, providing both food and cover. The juveniles of most of the species of resident fish that were abundant in the Project's reservoir were observed to use macrophyte beds as habitat (DES 2001b). Although sampling in macrophyte beds was not extensive, Chinook salmon were observed using macrophyte beds in the Rocky Reach reservoir (John Blum, EES (formerly DES), personal communication).

DO levels in dense macrophyte beds may fluctuate widely throughout the day, at times falling below the water quality criterion of 8.0 mg/L. During the day, aquatic plants produce oxygen while undergoing photosynthesis, which results in high DO levels that can exceed saturation levels. However, at night the macrophytes consume oxygen during their respiration cycle and DO levels and, in areas with minimal water circulation, the DO can drop below 8.0 mg/L. WDOE has expressed concern that fish habitat in areas of dense macrophyte growth may not meet water quality standards for salmon and other sensitive species.

Areas that are shallow, with low flow velocities and dense macrophyte growth are where water quality exceedances are most likely to occur, and these areas also provide suitable habitat for Chinook salmon, the primary sensitive species that would use this habitat type. The aquatic habitat map layers (DES 2001a) have been processed to show the locations where these three habitat features (shallow – less than 10 feet deep, velocities less than 0.1 feet per second, with dense macrophyte growth) are present (APPENDIX F:)

Chelan PUD will develop a sampling program, in consultation with WDOE, to determine if the water quality criteria for DO are met in these habitats. If DO exceedances are detected, further sampling will be conducted to determine if sensitive fish species use these habitats at the time of year when the DO exceedances occurred. If such exceedances are found in substantial areas of habitat where sensitive species are present, then Chelan PUD will consult with WDOE to determine if action is needed to reduce macrophyte growth and, if so, to develop and implement a reasonable and feasible macrophyte reduction plan.

4.5 SPCC Plan

Chelan PUD will continue to operate the Project in accordance with the SPCC Plan. The SPCC Plan will be updated and revised periodically as described in Section 2.6.2.

4.6 Columbia-Snake River Spill Response Initiative

Chelan PUD will implement the Columbia-Snake River Spill Response Initiative, as appropriate. The current schedule and more details are presented at the end of Section 2.6.1.

4.7 Comprehensive Plans for Sensitive Aquatic Organisms

The Rocky Reach Comprehensive Settlement Agreement and the HCP Agreement, with associated terms and conditions in the New License, provide the basis for compliance with the narrative components of the water quality standards as they relate to the protection of beneficial uses and habitat. Seven species of fish, Chinook salmon, sockeye salmon, coho salmon, steelhead trout, bull trout, white sturgeon and lamprey have been identified in the relicensing process and in ESA consultations as sensitive aquatic organisms. These species provide an appropriate bellwether for measuring whether the Project meets the water quality requirements to support the designated use of habitat for fish rearing and migration. The Comprehensive Plan has chapters specific to each of these species, which contain adaptive management plans for achievement of biological objectives. The major biological objectives from the Comprehensive Plan are summarized below. This table will be maintained consistent with the tables in the fish management plans.

Table 14: Biological Objectives in the Comprehensive Plan to Support Designated Beneficial Uses

Designated Beneficial Use	Biological Objective	Evaluation Timeframe	Actions if Objective Achieved	Alternative Management Actions
Salmonid Migration	HCP Plan Species (Chinook, Steelhead, Sockeye, Coho) 91% Project Passage Survival	By 2013	Maintain Action.	Additional Tools (Bypass modifications, spill, other)
Salmonid Harvest	HCP Plan Species NNI Hatchery Production Achieves 7%	By 2013	Maintain Action. Adjust 7% Production Level Every 10 Years	Modify hatchery facilities or use other method for artificial production (lake outplants)
Salmonid Rearing	HCP Plan Species Tributary Fund Implements Habitat Improvements For NNI	By 2013	Maintain Action.	Modify type of projects funded
Bull Trout Adult upstream migration	Take does not exceed 2% through the upstream fishway.	2005-2008	Maintain Action. No additional action needed.	Develop and implement a plan, in consultation with the RRFF, to address identified problem(s) as defined in section 4.1.3.
Bull Trout Adult downstream migration	Take does not exceed 5% passing through turbines; 2% passing through spillways; and 2% passing through the downstream bypass.	2005-2008	Maintain Action. No additional action needed.	Develop and implement a plan, in consultation with the RRFF, to address identified problem(s).
Bull Trout Adult rearing in the Reservoir	Take does not exceed 2 fish for the fish predator control program.	2005-2008	Maintain Action. No additional action needed.	Develop and implement a plan, in consultation with the RRFF, to address identified problem(s).
Bull Trout Sub-adult downstream migration	Take does not exceed limits when established by USFWS.	As recommended by the RRFF.	Maintain Action. No additional action needed.	Pursue feasibility of Project operations of fishway/bypass if migration problems are identified as defined in section 4.1.3.
Bull Trout Sub-adult rearing in the Reservoir	Take does not exceed limits when established by USFWS.	2005-2008	Maintain Action. No additional action needed.	Develop and implement a plan, in consultation with the RRFF, to address identified problem(s) as defined in section 4.1.3.

Table 14: Biological Objectives in the Comprehensive Plan to Support Designated Beneficial Uses

White Sturgeon Natural recruitment	Juvenile recruitment by existing natural population (pre-stocking)	Years 3 - 25	Maintain Action. No additional action needed.	Develop and implement a plan, in consultation with the RRFF, to address identified problem(s).
White Sturgeon Natural recruitment	Naturally recruited juvenile progeny of hatchery-stocked fish (post-stocking)	Years 25 - 50	Maintain Action. No additional action needed.	Develop and implement a plan, in consultation with the RRFF, to address identified problem(s).
White Sturgeon Harvest	Success in creating population with a stable age-structure that allows for limited harvest	Years 20 - 50	Maintain Action. No additional action needed.	Develop and implement a plan, in consultation with the RRFF, to address identified problem(s).
Pacific Lamprey Adult Upstream Migration	Adult passage success (definition to be determined) Investigate and implement reasonable and feasible technologies shown to be effective at other dams	By Year 10	Develop criteria for success (e.g. outcome-based standard) Maintain Action. No additional action needed.	Develop and implement a plan, in consultation with the RRFF, to address identified problem(s).
Pacific Lamprey Juvenile Downstream Migration	Juvenile passage success (definition to be determined) Investigate and implement reasonable and feasible technologies shown to be effective at other dams	By Year ??	Develop criteria for success (e.g. outcome-based standard) Maintain Action. No additional action needed.	Develop and implement a plan, in consultation with the RRFF, to address identified problem(s).
Pacific Lamprey Juvenile Rearing	Maintain or Enhance Habitat Quality for Juveniles	By Year ??	Maintain Action. No additional action needed.	Develop and implement a plan, in consultation with the RRFF, to address identified problem(s).
Native, Non-Stocked Resident Fish Species Rearing and Spawning	No negative population trend caused by ongoing Project operations.	Every 10 years	Maintain Action. No additional action needed.	Develop and implement a plan, in consultation with the RRFF, to address identified problem(s).

4.8 Timeline for Water Quality Management Plan and Sensitive Aquatic Organism Comprehensive Plans

The protection, mitigation and enhancement measures detailed in this section of the Water Quality Management Plan, combined with the comprehensive plans developed for sensitive aquatic species and the HCP Agreement, constitute Chelan PUD's proposal to provide reasonable assurance for 401 Certification that the Project will comply with all applicable water quality standards and criteria. In the 2003 water quality standards, there is a section regarding compliance schedules for dams. In this section, the following relates to 401 Certification:

> "If the department is acting on an application for a water quality certification, the approved water quality attainment plan may be used by the department in its determination that there is reasonable assurance that the dam will not cause or contribute to a violation of the water quality standards."

Although at this time Chelan PUD believes the Project complies with all water quality standards and criteria, the actions proposed for TDG and water temperature will serve as a schedule to confirm that compliance has been achieved. In addition, implementation of the actions in the comprehensive plans for sensitive aquatic species and continued implementation of the HCP Agreement over the next several years will provide additional assurance that the designated beneficial uses of the Project's waters have been supported.

The year 2013 is a pivotal year for achievement of survival standards in the HCP Agreement, with likely conclusion of survival studies for yearling Chinook and steelhead in 2007, and determination of long-term requirements for fish passage spill by 2011. Similarly, the early results of implementation of a new Project license will potentially also be available by 2011. With these dates in mind, WDOE has proposed to base their 401 Certification on a compliance schedule for review of actions, results and the record of compliance with water quality standards and criteria. This schedule, Figure 31, incorporates checkpoints for three lines of evidence for support of designated beneficial uses. These are achievement of HCP survival standards, implementation of comprehensive plans for sensitive aquatic species, and conduct of monitoring and other actions under the 401 Certification. Milestones are identified in 2007, when issuance of a new Project FERC license is expected, 2011 when HCP survival standards will be achieved, 401 Certification actions, monitoring and evaluation results will be available, and initial implementation of new Project license comprehensive plans will be well underway. The timeline incorporates an additional window of time, until 2015, to track results and implement additional actions for water quality standard compliance, if necessary. If there is a failure to confirm compliance with water quality standards by 2015, then there is a two year window to pursue other means to achieve compliance. These other actions could include a process to modify the applicable standards through rulemaking or such alternative process that may otherwise be authorized under applicable state and federal law.

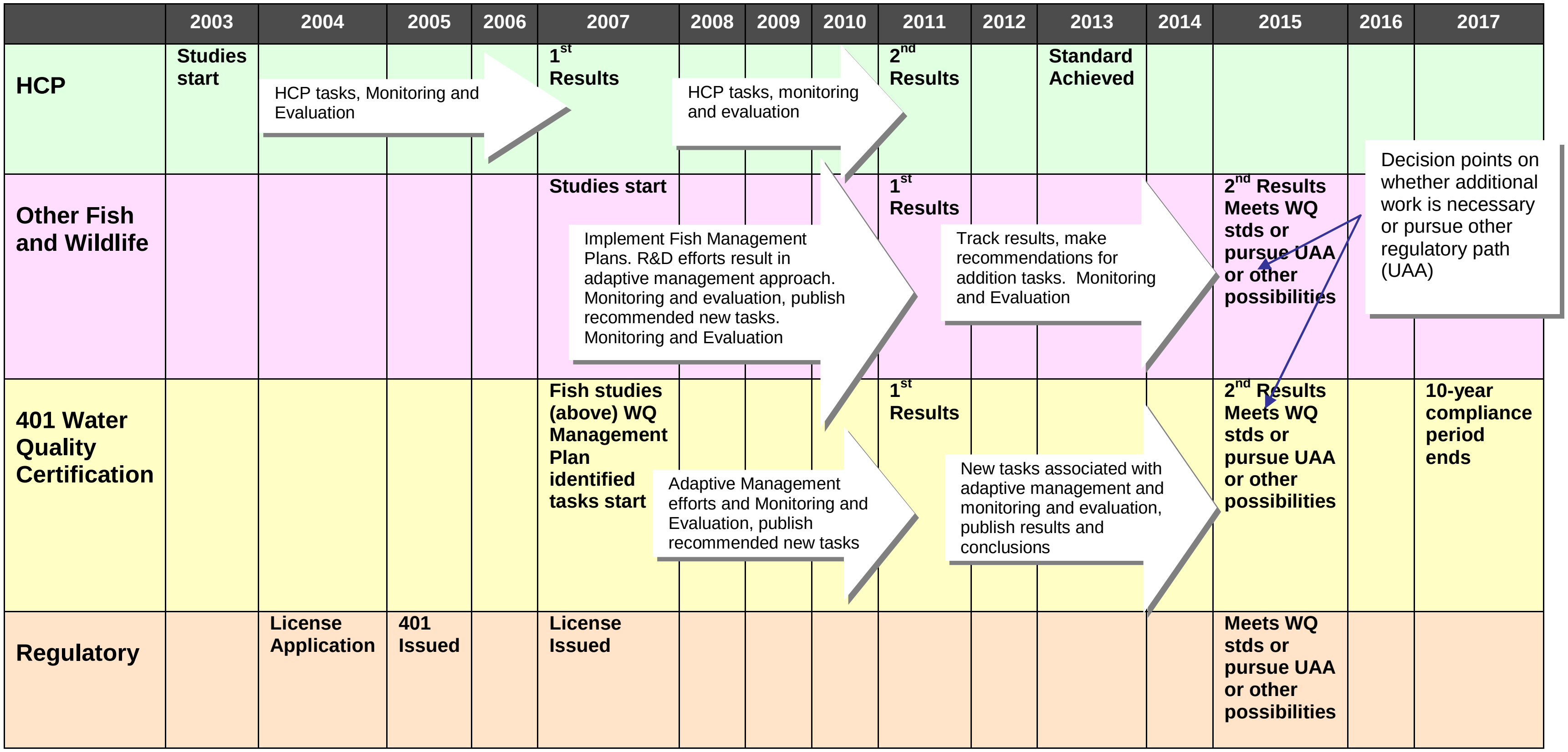


Figure 31: Draft Conceptual Approach and Timeline for Compliance with Water Quality Standards (WDOE, January 2005)

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