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Mainstem/Systemwide Water Quality Program Summary

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I. Program Description

I.A. Program Purpose

The purpose of this document is to provide the reader with an overview of mainstem Columbia River and Snake River water quality issues, technical challenges, and institutional activities. The document describes the past and present knowledge, programs, and projects, as well as the future needs of water quality for the mainstem from a systemwide perspective. The substance of this report was drawn from many existing reports, documents, implementation plans, and issue papers. The report also reflects the input of the contributors listed on the title page.

A major portion of the information discussed below was derived from the 2000 National Marine Fisheries Service (NMFS) Federal Columbia River Power System (FCRPS) Biological Opinion. The range of topics addressed in the 2000 biological opinion include: technical background, existing mainstem water quality issues, effects of the FCRPS configuration and operations, ongoing funded projects, and future needs or action items. During the development of the 2000 biological opinion, NMFS worked closely with the U.S. Environmental Protection Agency (EPA) and the Action Agencies (U.S. Army Corps of Engineers, Bonneville Power Administration, and U.S. Bureau of Reclamation), to align Federal efforts responding to two congressional acts, i.e., the Endangered Species Act (ESA) and the Clean Water Act (CWA). In pursuing this effort the agencies recognized the need for a new and focused approach to dealing with water quality as a key element in the restoration of the anadromous fish runs of the Columbia River basin.

Another source of information for this report is the U.S. Fish and Wildlife Service's (USFWS) 2000 Effects to Listed Species from Operations of the FCRPS. The USFWS biological opinion analyzed the effects of the FCRPS on the bull trout in the mainstem Snake and Columbia rivers.

In recent years water quality efforts by the EPA have been particularly vigorous. Input to the present document from the EPA has been included, especially with regard to water quality limited areas of the mainstem (CWA 303(d) listings) concerning water temperature and dissolved gas. Finally, many contributions to this document were made by the Action Agencies (AA). In response to the biological opinions, the U.S. Army Corps of Engineers (Corps), Bonneville Power Administration (BPA), and the U.S. Bureau of Reclamation (BOR) have been developing one- and five-year implementation plans responsive to both of the biological opinions. Pertinent portions of work products produced in those efforts are reflected herein.

I.B. Geographic Scope

The geographic scope of this document encompasses the mainstem Columbia and Snake rivers from the international boundary between the United States and Canada on the Columbia River, and from the Hells Canyon Dam on the Snake River downstream, to and including the estuary. With respect to the FCRPS projects, the document considers the water quality effects of the existing hydropower project configuration, its continued operation and maintenance of the powerhouses, and associated reservoirs known collectively as the FCRPS and operated as a coordinated system for purposes of power production, flood control, navigation, and other purposes on behalf of the Federal government. The facilities that constitute the FCRPS are

- the Dworshak, Lower Granite, Little Goose, Lower Monumental, and Ice Harbor dams, power plants, and reservoirs in the Snake River basin;
- the Grand Coulee and Chief Joseph dams, power plants, and reservoirs in the upper Columbia River basin;
- the McNary, John Day, The Dalles, and Bonneville dams, power plants, and reservoirs in the lower Columbia River basin.

In addition, this document will consider the effects on mainstem water quality due to the irrigation wasteway returns of Banks Lake water through the BOR's Columbia Basin Project. Federal projects located in Montana, i.e., the Libby and Hungry Horse dams, are also components of the FCRPS. The effects on water quality of operations at these projects located on the Kootenai and Flathead rivers, respectively, will also be addressed in this document although they are not located on "mainstem" river reaches.

I.C. Technical Scope

I.C.1. National Marine Fisheries Service 2000 FCRPS Biological Opinion

I.C.1.a. Background

Water quality throughout the Columbia River basin has been degraded by human activities such as dams and diversion structures, water withdrawals, farming and grazing, road construction, timber harvest activities, mining activities, and urbanization. The waters in major sections of the mainstem presently do not meet Federally-approved, state and Tribal water quality standards and are now listed as water-quality-limited under Section 303(d) of the CWA. Tributary water quality problems contribute to poor water quality where sediment and contaminants from the tributaries settle in mainstem reaches and the estuary.

Major reaches of the lower Columbia and lower Snake rivers are on the 303(d) list for not meeting water quality standards for temperature, total dissolved gas and sediments (see Table 1). Temperature alterations affect salmonid metabolism, growth rate, and disease resistance, as well as the timing of adult migrations, fry emergence, and smoltification. Many factors can cause high stream temperatures. Retarded flow due to impoundments in the mainstem is a major factor in altered thermal conditions.

Some of the water withdrawn from streams eventually returns to the mainstem Columbia and Snake rivers as agricultural runoff. Another portion is accounted for through groundwater recharge, while crops consume a large proportion as well. Return water from irrigated fields can introduce nutrients, sediments and pesticides into streams and rivers. The full extent of mainstem water quality degradation due to transport of these pollutants is unknown. Additionally, the actual impact to fish and other aquatic species is unknown.

On a larger landscape scale, human activities have affected the timing and amount of peak water runoff from rain and snowmelt. Forest and range management practices have changed vegetation types and density, which can affect the timing and duration of runoff. Many riparian areas, flood plains, and wetlands that once stored water during periods of high runoff have been developed. Urbanization paves over or compacts soil and increases the amount and pattern of runoff reaching rivers and streams. Many tributaries have been significantly depleted by water diversions. In 1993, fish and wildlife agency, Tribal, and conservation group experts estimated that 80% of 153 Oregon tributaries had low-flow problems (two-thirds caused at least in part by irrigation withdrawals) (OWRD 1993).

I.C.1.b. Total Dissolved Gas

The operation and configuration of the FCRPS, as well as other non-Federal projects on the Columbia River, have two primary effects on water-quality-related salmon survival: dissolved gas supersaturation and temperature.

Total dissolved gas (TDG) is generated when water is spilled at dams. Falling water entrains volumes of air and carries the air into the depths of the stilling basin. Stilling basins are designed to dissipate energy and are often 50 to 60 feet deep. Hydrostatic pressure at depth in the basin forces the entrained gases into solution, causing supersaturation. Supersaturated gases in river water can off-gas at any air/water interface, e.g., the river surface, wave action on the surface, or air bubbles from rapids and riffles; however, TDG conditions often persist for many miles below spilling dams.

Water supersaturated with TDG can produce a hazardous condition for aquatic organisms. Fish relying on dissolved oxygen for their life processes become equilibrated with the gaseous state of the river. Gas is absorbed into the bloodstream of fish during respiration. Supersaturated gases in fish tissues tend to pass from the dissolved state to the gaseous phase as internal bubbles or blisters. This condition is called Gas Bubble Trauma (GBT) and can be debilitating and fatal to the afflicted organism, which includes upstream and downstream migrating salmonids (Ebel and Raymond 1976). Susceptibility to GBT is highest near the water surface, because the reduced hydrostatic pressure allows the gases to come out of solution.

I.C.1.c. Biological Opinion Spill Program

Spilling waters at the projects is the safest and most benign way to move nontransported juvenile downstream migrants past the dams. Spilling large volumes of water sweeps the fish in those waters over the dam and avoids passage through the turbines. The TDG generated by this strategy can exceed current water quality standards (110% TDG standard set by the EPA, the affected states, and the Colville Confederated Tribes). As a result, the Federal government has to seek temporary variances of those standards before spilling water to benefit juvenile salmon.

Since 1992, the NMFS biological opinions have relied on voluntary spill as a safe and effective means of increasing juvenile passage and survival at the mainstem projects. The provision of spill as a part of the NMFS biological opinion has evolved over the past decade. Before, the spill was managed according to the 1989 Spill Memorandum of Agreement (Agreement) which allowed for spill at four Federal projects: Lower Monumental, Ice Harbor, John Day, and The Dalles. In 1994, substantial changes were made to the existing spill program. A request was made to implement spill to achieve an 80% fish passage efficiency (FPE) at all projects, including transport projects. The increase in spill was not provided until a variance was granted from the state water quality agencies. At the time, it was recognized that the river would be managed based on physical concentrations of TDG and a biological monitoring program would be developed and implemented.

In 1995, the region's fishery agencies and the Tribes published the "Spill and 1995 Risk Management" report (WDFW, ODFW, IDFG, and CRITFC 1995). This assessment considered the benefits of spill to increase juvenile fish passage, the risks associated with spill-generated gas, and the survival of juveniles through other routes of passage. The conclusion of that report was that juvenile mortality associated with turbine passage exceeded that due to TDG from spill until the TDG exceeded 120 to 125%. Recognizing the inherent risk in the application of this conclusion to river operations, the agencies and Tribes urged implementation of an extensive physical and biological monitoring program to track the effects of the spill program. Spill was implemented in 1995 and beyond as described in the 1995 biological opinion. Spill levels were designed to achieve the 80% FPE, but were constrained by the 115/120% TDG limits in the forebay and tailrace, respectively. A rigorous biological monitoring program was developed and initiated to accompany the spill program.

The biological opinion spill program has been modified twice since that time. In the 1998 supplement to the biological opinion the threshold for reducing voluntary spill was changed to a real time physical measurement of dissolved gas rather than a calculated spill volume equivalent to an 80% FPE. From that point forward spill was retarded if the forebay and tailrace TDG exceeded 115% or 120%, respectively. The 2000 biological opinion has defined biological performance standards and set numeric goals to be achieved by the AA. These hydrosystem performance standards are discussed in the Reasonable and Prudent Alternatives (Section 9.0) of the 2000 biological opinion. This new strategy calls for the AAs to fulfill the biological performance standards through various system configuration and operational modifications. In time, as other of the longer term actions help achieve performance standards in the Columbia River basin and fish numbers begin to increase, the spill program may be reduced.

I.C.1.d. Gas Bubble Trauma Monitoring Program

Since 1995, the biological monitoring program has recorded annually the effects of the FCRPS biological opinion spill program. The overall number of fish affected with GBT signs observed over the years has proven to be lower than originally anticipated when the biological opinion was developed. The biological monitoring program has shown that the average incidence of signs increases above 1% of the migrants sampled when TDG exceeds 115%. When fish are exposed to gas levels greater than 120%, there is an increasing trend in incidence and severity of these signs. The most severe signs display a similar trend above 125%. For example, the spring and summer months of 1996 and 1997 were characterized by high volumes of involuntary spill with TDG levels ranging from 130% to 140% for days. In these two years, the incidence of GBT signs was 3.2% to 3.3% of the fish observed. The freshets of 1995, 1998, and 1999 were more average in runoff volume and the signs ranged from 0.04% to 0.7% of all fish sampled, thereby demonstrating the minimal effect of biological opinion spill levels with TDG levels managed to 115% and 120% in the project forebays and tailraces, respectively.

A critical point assumed in the early risk assessment was that fish migrate at a protective or compensatory depth. Studies since 1995 have shown that juveniles travel at depths sufficient to negate mortalities predicted from the earlier 1970s laboratory studies (the basis for the current TDG standards) conducted in shallow water conditions. Furthermore, recent studies of adult swimming depths revealed similar findings. Adults have been tagged with radio transmitters capable of detecting and recording travel depths. The findings indicated that adult fish move at depths that would compensate for TDG of 115% to 140%.

The five years of physical gas monitoring have demonstrated a sensitive and accurate monitoring system. During water years characterized by runoff volumes where the spill is due primarily to the biological opinion voluntary spill program, the TDG produced is accurately detected and spill adjustments can be made to restrict gas below the 120% level. TDG monitoring also detects excursions above 120% TDG caused by involuntary spill during high water years with large freshet volumes. Physical monitoring has also recorded the beneficial effects of the various gas abatement efforts implemented over the last five years in the hydrosystem.

I.C.1.e. Summary of Past Dissolved Gas Research Results

This summary is based on Appendix E of the 2000 NMFS FCRPS Biological Opinion, Risk Assessment for the Spill Program. One section of Appendix E reviewed the scientific record of laboratory and field investigations of TDG biological effects including the studies used in establishing the EPA TDG water quality standard. The following provides key highlights of past research.

The effect of high TDG on the aquatic species of the rivers is well documented (Beiningen and Ebel 1970; Ebel et al. 1975; Weitkamp and Katz 1980). The precise relationship between dissolved gas and fish mortality was unknown in the 1960s and 1970s. Early studies did, however, demonstrate a relationship between biological effects and TDG level, exposure duration, depth of exposure, water temperature, species, fish condition, and life stage (Ebel et al. 1975; Blahm et al. 1973; Dawley et al. 1975; Dawley and Ebel 1975; Blahm et al. 1975; Weitkamp 1976; Weitkamp and Katz 1980; Jensen et al. 1986).

Efforts to protect fish in the late 1960s and through the 1970s focused on determining a lethal TDG threshold. Most of the research investigated dissolved gas levels ranging from 110% to 140% TDG supersaturation. However, many of the early studies were conducted in shallow laboratory tanks and found mortalities at 115% TDG after 3 to 4 weeks of exposure (Dawley and Ebel 1975). On the basis of those early bioassays, the EPA set the dissolved gas standard at 110% TDG. However, it has been suggested that defensible gas limits for a deep, free-flowing river environment could be set as high as 120% TDG (Weitkamp and Katz 1980; WDFW, ODFW, IDFG, and CRITFC 1995). The findings of the spill monitoring program discussed above support this suggestion, and also suggest consideration be given to permanently modifying the water quality standard or establishing a site-specific criterion for TDG in the Columbia River.

Recent studies have pursued the relationship of exposure to TDG supersaturation and the presence, progression, severity, and relevance of GBT signs, especially as related to the biological monitoring program. The conventional signs used in GBT studies and monitoring are bubbles or blisters in the lateral line, fins, and gill filaments. Maule et al. (1997a) found that no single GBT sign can be relied on as the sole precursor of lethal conditions in the field, but GBT is most often progressive, and its severity is a function of TDG level and exposure time. If a group of fish is exposed to TDG supersaturation for a sufficiently long period, the outcome is not in question. Signs of GBT will develop. Therefore, careful, rigorous monitoring of a population of migrants as they move through the FCRPS will detect GBT. However, if TDG is low and passage time is less than the threshold time for development of signs, the juveniles will have moved beyond the dissolved gas effects of the river.

In addition, gas solubility increases with increasing pressure. For each meter of depth there is a 10% reduction in the TDG saturation level relative the surface saturation (Weitkamp and Katz 1980). By the mid-1970s, researchers had gathered information suggesting that depth compensation occurs and has the biological effect that gas solubility calculations would predict. Maule et al. (1997b) observed that salmonids may migrate at protective depths. In that pilot study, few fish were successfully tagged and tracked, and the data were insufficient for statistical analysis. However, the results suggested that the depth of the tagged fish would compensate for a surface TDG level of up to approximately 124%.

This level of depth compensation is enough to negate predicted mortalities from the mid-1970s laboratory studies conducted in shallow water. It also may explain why the annual biological monitoring program detects fewer GBT signs than might be expected. The investigators (Maule et. al 1997) concluded that a voluntary spill program with gas caps of 115% in forebays and 120% in tailraces can be expected to prevent GBT in juvenile chinook and pose little threat to the more sensitive steelhead.

I.C.1.f. Water Temperature

Hydroelectric dams have modified natural temperature regimes in the mainstream Columbia River. Snake River basin storage reservoirs are known to affect water temperatures (Yearsley 1999) by extending water residence times and by changing the heat exchange characteristics of affected river reaches. In particular, seasonal temperature fluctuations generally decrease below larger storage reservoirs that thermally stratify and have hypolimnetic discharges. Downstream temperatures are cooler in the summer as cold hypolimnetic waters are discharged, but warmer in the fall as energy stored in the epilimnion during the summer is released (Spence et al. 1996). Because of the thermal storage provided by these large reservoirs, seasonal variations in downstream temperatures are altered in much the same way as seasonal variations in streamflow.

Lower Columbia and Snake river FCRPS reservoirs are considered run-of-river reservoirs with reduced water residence time compared with large storage projects. Mainstem run-of-river reservoirs generally have relatively weak thermal stratification. Thus, in those reservoirs, water temperature will be relatively uniform from top to bottom. The FCRPS reservoirs can also affect water temperatures, however, by extending water residence times and changing the heat exchange characteristics in the lower Snake and Columbia rivers, compared with an unimpounded river (Yearsley 1999). The Independent Scientific Group (2000) concluded that “mainstem reservoirs in the Snake and Columbia rivers have created shallow, slow-moving reaches of shorelines where solar heating has raised temperatures of salmon rearing habitat above tolerable levels”, and that the operation of “storage impoundments in the Columbia River basin [has] shifted annual peak temperatures of the mainstem . . . to later in the season, when late summer and fall migrating salmonids encounter them.”

Water temperature conditions have a complex array of effects on salmonids. Intergravel water temperatures affect the rate of embryonic development, with about 1,000 degree-days needed for incubation and emergence (Weatherley and Gill 1995). Post-emergence growth rates are directly related to water temperature. Water temperatures experienced by migrating juvenile salmon have been shown to affect survival (Connor et al. 1998; Smith et al. 1998; Muir et al. 1999).

An emerging issue is potential water temperature effects on juvenile migration timing. It is known that juvenile fall chinook now migrate up to four weeks later than they did before development of the Hells Canyon Complex and the Corps' four lower Snake River projects (NMFS 2000b). The working hypothesis is that juvenile migration timing during incubation and early rearing life stages is delayed by cooler than historical water temperatures, which occur primarily above the lower Snake projects but directly below the Hells Canyon Complex. This effect may be exacerbated by delayed spawning due to excessively warm fall temperatures. Because water temperatures and juvenile salmon mortality rates increase from mid-July through mid-September, delayed outmigration timing reduces juvenile fall chinook survival through Lower Granite Reservoir.

During July and August of some years, warm water from the lower Snake River enters the Columbia River in the McNary pool. This warm water plume tends to remain along the south (Oregon) shoreline as it approaches McNary Dam. Turbine unit operations at McNary Dam during the summer low flow and warm temperature conditions can influence the temperature of water drawn into the juvenile fish collection gallery. Thermal profile data collected at McNary Dam have been used to develop special powerhouse operations (i.e., north powerhouse loading) to partially alleviate the potential for thermal stress on juvenile summer migrants that are collected for transportation. Even when south powerhouse units are not operated, however, warm water from along the south shoreline can still be drawn toward the northern operating turbine units.

Immigrating adults can be delayed by excessively warm water temperatures (Karr et al. 1998). In addition, fall chinook spawning is inhibited by temperatures above 61°F (16°C) (McCullough 1999). Delay can reduce the ability of adult fish to survive until spawning, as well as their vigor and fecundity during spawning.

Water temperature also indirectly affects salmon survival. Foraging rates of piscivorous fish are directly related to temperature (Vigg and Burley 1991), and the rates of infection and mortality of several diseases are known to be directly related to temperature.

Thus, operation of storage reservoirs affects both the thermal characteristics of the river and the thermally-regulated aspects of salmon survival. For this reason, the thermal effects of reservoir operation are an important consideration in developing system operations aimed at protecting and restoring listed salmonids.

Water temperature also affects the rate of physiological development in smolts. Zaugg (1981) found that exposure of steelhead smolts to water temperatures greater than 12°C (53.6^{0}F) resulted in reduced ATPase activity and migratory behavior. Because dams cause migrational delay, smolts are exposed to seasonal increases in water temperature that can result in increased rates of residualism. The effects of increased water temperatures on other salmonids is less clear and warrants further investigation.

I.C.1.g. Operation of Dworshak Reservoir to Control Snake River Water Temperature

Lower Granite Reservoir occupies the Snake River from river mile (RM) 108 to RM 148 and backs water into the Snake and Clearwater rivers a few miles upstream of their confluence near Lewiston, Idaho. It is the first major reservoir encountered by emigrating Snake River juvenile salmon and the last major reservoir negotiated by immigrating adults. A substantial portion of juvenile fall chinook salmon mortality occurs in Lower Granite Reservoir (Smith et al. 1998; Connor et al. 1998; Muir et al. 1999).

During the summer, all emigrating juveniles collected at Lower Granite Dam are transported to release points downstream of Bonneville Dam, the lowermost dam on the Columbia River. In recent years, up to 50% of the outmigrating Snake River fall chinook juveniles passing Lower Granite Dam have been collected and transported (Peters et al. 1999). For these transported fish, Lower Granite Reservoir is the last reservoir transited during their seaward migrations.

Survival of PIT-tagged juvenile fall chinook salmon from release points in the Snake and Clearwater rivers to Lower Granite Dam is strongly correlated with water temperature, as well as flow and turbidity, in Lower Granite Reservoir (NMFS 2000b). To minimize water temperature-related effects on juvenile fall chinook, Dworshak Dam on the North Fork Clearwater, about 2 river miles upstream of the Clearwater River and 60 miles from Lower Granite Reservoir, is routinely operated to release large amounts of cool water during the months of July and August to reduce water temperatures in Lower Granite Reservoir and downstream reaches. Dworshak Reservoir is a deep impoundment (over 600 feet deep at full pool) that stratifies in the summer, and Dworshak Dam is equipped with a variable-intake depth-release structure that facilitates selecting a specific discharge water temperature. During July and August, reservoir managers typically release water at 48° to 50°F (9° to 10°C) at the request of regional salmon managers. Cooler releases are possible but may result in adverse juvenile salmon growth conditions in the Clearwater River. This operation reduces ambient water temperature by approximately 4° to 6°F (-2° to -3°C) at Lower Granite Dam when elevated temperatures are a concern in the Snake River (July and August).

I.C.1.h. Water Quality Effects of the Columbia Basin Project

The Columbia Basin Project is BOR’s largest irrigation project in the upper Columbia River basin (above McNary Dam), diverting 2.7 Maf of water to irrigate 672,000 acres of land (BOR 2000a). Project lands extend from Billy Clapp Lake, about 40 miles south of Grand Coulee Dam, to the edges of the Pasco and Richland, Washington, metropolitan area. The continued operation of the Columbia Basin Project may affect listed salmon and steelhead.

Columbia Basin Project wasteways deliver irrigation wastewater to several locations in the Columbia River downstream from Rock Island Dam. The BOR estimates that the total combined capacity of these wasteways to be less than 700 cfs (BOR 2000b). Temperatures of return flows occasionally range up to 90°F (32°C) (BOR 2000c). Irrigation return flows may also contain high concentrations of plant nutrients (nitrogen and phosphorus), sediments, and pesticide and herbicide residues. The effects of such pollution in the Columbia River is probably small but unknown, given the river’s dilution capacity (wasteway capacity is about 0.4% of average river flows). Furthermore, water use in the Columbia Basin Project is increasingly efficient (Montgomery Water Group 1997). That is, deliveries to farmlands are approaching the amount of water required by crops. Therefore, less water is wasted, and less wastewater and pollutants return to the river in project wasteways. NMFS is concerned, however, that even small concentrations of some agricultural chemicals can adversely affect the aquatic community in general and salmon in particular (Scholz, letter, 2001; Waring and Moore 1997; Washington State Pesticide/ESA Task Force 2001).

Spawning adult chinook salmon have been observed in the lower portions of some of the Columbia Basin Project wasteways. Given the poor water quality in these wasteways, it is likely that spawning success is low to nonexistent. Spawning fish in this area are primarily unlisted
upriver bright Columbia River fall chinook salmon. NMFS is unaware of any information on whether these wasteways attract listed salmon species.

I.C.2. Environmental Protection Agency and the Clean Water Act

I.C.2.a. Background

The CWA provides the statutory basis for water quality regulation and management in the United States. It provides programs addressing the assessment of water quality in our nation's waters, restoration of impaired waterbodies, permitting of point sources of pollution and management of nonpoint pollution sources. Many of the programs established by the CWA are implemented by the state water quality agencies with EPA serving in an oversight capacity.

Water quality standards are set by the states and Tribes for all surface waters, and they identify the uses for each waterbody. For example, drinking water supply, contact recreation (swimming), and aquatic life support (fishing). They also provide the scientific criteria to support that use. states and Tribes are required to periodically review their water quality standards and submit all changes to EPA for approval. The water quality standards serve as the foundation for most other CWA programs.

Every 2 years, the states are required to assess the condition of all surface waters and submit a list of impaired waters (those waters which do not meet water quality standards) to EPA. This list is referred to as the 303(d) List since it is required by Section 303(d) of the CWA. EPA is required to review these lists and make an approval or disapproval decision. If disapproved, EPA is required to revise and reissue the list.

I.C.2.b.303(d) Description, Mainstem List and Total Maximum Daily Loads

Section 303(d) of the CWA further requires that a Total Maximum Daily Load (TMDL) be established for all waterbodies on the 303(d) List. A TMDL is a calculation of the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards, and an allocation of that amount to the pollutant's sources. A TMDL is the sum of the allowable loads of a single pollutant from all contributing point and non-point sources. The calculation must include a margin of safety to ensure that the waterbody can be used for the purposes the state has designated. The calculation must also account for seasonal variation in water quality. Total Maximum Daily Loads for both TDG and water temperature are presently under development.

The Columbia River basin mainstem TMDLs will include that portion of the Snake River beginning at the mouth of the Salmon River (RM 188) and extending to the confluence of the Snake River with the Columbia River. The TMDLs will also include all of the Columbia River that is located in the United States, including Lake Roosevelt (Table 1). EPA will take the lead for developing the Temperature TMDL for both rivers and the states will issue the Temperature TMDLs as appropriate to each state. EPA will develop and issue the Temperature and TDG TMDLs for waters within the Tribal reservations. The states will take the lead for developing and issuing the TDG TMDL for the rest of the two rivers. The parties have agreed to cooperate in the collection of data, making technical and policy decisions, and providing for public participation.

Table 1. 1998 303(d) Listings for the Mainstem Columbia River and the Snake River Below the Salmon River.

Parameter	Oregon	Washington	Idaho
Arsenic			
Columbia River	Mouth to Willamette River (RM 86)	Mouth at Pacific Ocean to McNary Dam (RM 292) (WA-CR-1010 & 1020)	n/a
		Roosevelt Lake. Grand Coulee Dam (RM 596.6) to Canadian Border (RM 745.0). This segment partially under jurisdiction of Colville and Spokane Tribes (WA-CR-1060).	
Bacteria (OR) / Fecal Coliform (WA)			
Columbia River	Mouth to Willamette River (RM 86)	Mouth at Pacific Ocean to Bonneville Dam (RM 146.1) (WA-CR-1010)	n/a
Bis(2-ethylhexyl) Phthalate`			
Columbia River	none	Mouth at Pacific Ocean to Bonneville Dam (RM 146.1) (WA-CR-1010)	n/a
DDT/DDE			
Columbia River	Mouth to Bonneville Dam (RM 147)	Mouth at Pacific Ocean to Bonneville Dam (RM 146.1) (WA-CR-1010) (4,4-DDE)	n/a
Dieldrin			
Columbia River	none	Mouth at Pacific Ocean to Bonneville Dam (RM 146.1) (WA-CR-1010)	n/a
Dissolved Oxygen			
Columbia River	Mouth to Willamette River (RM 86)	Mouth at Pacific Ocean to Bonneville Dam (RM 146.1) (WA-CR-1010)	n/a
		Roosevelt Lake. Grand Coulee Dam (RM 596.6) to Canadian Border (RM 745.0). This segment partially under jurisdiction of Colville and Spokane Tribes (WA-CR-1060).	
Snake River	none	Mouth at Columbia (RM324.3) to SF Palouse River (RM 59.3) (WA-33-1010)	none
Mercury			

Parameter		Oregon	Washington	Idaho
	Columbia River	none	Roosevelt Lake. Grand Coulee Dam (RM 596.6) to Canadian Border (RM 745.0). This segment partially under jurisdiction of Colville and Spokane Tribes (WA-CR-1060).	none
	Snake River	WA border to Salmon River	none	none
PCB				
	Columbia River	Mouth to Bonneville Dam (RM 147)	Mouth at Pacific Ocean to Bonneville Dam (RM 146.1) (WA-CR-1010) (PCB-1248, 1254, 1260)	n/a
pH				
	Columbia River	Tenasillahe Island to Bonneville Dam (RM 147)	Yakima River (RM 335.2) to Priest Rapids Dam (RM 397.1) (WA-CR-1030)	n/a
Sediment Bioassay				
	Columbia River	none	Mouth at Pacific Ocean to Yakima River (RM335.2) (WA-CR-1010, 1020, 1026, 1028)	n/a
			Roosevelt Lake. Grand Coulee Dam (RM 596.6) to Canadian Border (RM 745.0). This segment partially under jurisdiction of Colville and Spokane Tribes (WA-CR-1060).	
Temperature				
	Columbia River	Mouth to WA Border (RM 309)	Mouth at Pacific Ocean to Washington/ Oregon Border (RM 309.3) (WA-CR-1010, 1020, 1026)	n/a
			Chief Joseph Dam (RM 545.1) to Grand Coulee Dam (RM 596.6) (WA-CR-1050)	
			Roosevelt Lake. Grand Coulee Dam (RM 596.6) to Canadian Border (RM 745.0). This segment partially under jurisdiction of Colville and Spokane Tribes (WA-CR-1060).	
	Snake River	WA border to Salmon River	Mouth at Columbia (RM324.3) to SF Palouse River (RM 59.3) (WA-33-1010)	WA border to Salmon River
			Palouse River (RM 59.5) to Clearwater River (RM 139.3) (WA-35-1010)	
			Clearwater River (RM 139.3) to Oregon Border (RM 176.1) (WA-35-1020)	
Total Dissolved Gas				
	Columbia River	Tenasillahe Island to WA Border (RM 309)	Mouth at Pacific Ocean to Washington/ Oregon Border (RM 309.3) (WA-CR-1010, 1020, 1026)	n/a

Parameter		Oregon	Washington	Idaho
			Yakima River (RM 335.2) to Grand Coulee Dam (RM 596.6) (WA-CR-1030, 1040, 1050)	
			Roosevelt Lake. Grand Coulee Dam (RM 596.6) to Canadian Border (RM 745.0). This segment partially under jurisdiction of Colville and Spokane Tribes (WA-CR-1060).	
	Snake River	none	Mouth at Columbia (RM324.3) to SF Palouse River (RM 59.3) (WA-33-1010)	none
			Palouse River (RM 59.5) to Clearwater River (RM 139.3) (WA-35-1010)	
Water Column Bioassay				
	Columbia River	none	Priest Rapids Dam (RM397.1) to Chief Joseph Dam (RM 545.1) (WA-CR-1040)	n/a

Notes:
DDT/DDE listings in Oregon were based on fish tissue data, not water column data
PCB listings in Oregon were based on fish tissue data, not water column data
Temperature listing for the Snake River in Idaho (WA border to Salmon River) is currently proposed as part of EPA's promulgation associated with the partial disapproval of Idaho's 1998 303(d) List

TMDLs are implemented through the National Pollutant Discharge Elimination System (NPDES) permit program and the state's nonpoint source programs. The states of Washington and Oregon administer the NPDES program in their respective states while EPA administers the program for point source discharges in Idaho, on Tribal lands and from Federal facilities in Washington. If a TMDL has been established for the waterbody into which a point source discharges, the NPDES permit must be written consistent with the allocations established in the TMDL. A large number of Federal, state, and local programs are utilized to address the water quality improvements needed to meet allocations for non-point sources.

I.C.2.c. Lower Columbia River Estuary Program

Recognizing the importance of the Columbia River Estuary, Washington, Oregon, and EPA have worked together to address the environmental, recreational and economic issues facing the lower Columbia River. In 1995, they initiated the Lower Columbia River Estuary Program. The Estuary Program consists of agricultural interests, industry, ports, environmental groups, Tribes, recreation groups, commercial fishing interests, and Federal, state and municipal governments, and agencies. The program aims to develop actions to preserve and enhance the water quality of the river while supporting its biological and human communities.

The Lower Columbia River Estuary Program is examining seven priority issues which will act as springboards for the development of action plans designed to protect the river. The issues are: biological integrity of the estuary system; impacts of future population growth; habitat loss and modification; toxics in sediments and fish tissue; conventional pollutants; public awareness and stewardship; and institutional constraints.

I.C.3. U.S. Fish and Wildlife Service 2000 FCRPS Biological Opinion

I.C.3.a. Background

Listed resident fish addressed on the USFWS December 2000 Biological Opinion on operations of the FCRPS include bull trout and the Kootenai River population of white sturgeon. Both species are adapted to relatively cold waters, and believed to be subject to the effects of TDG supersaturation. Directly or indirectly, operations of the various projects of the FCRPS may affect water temperatures and/or TDG. Stream reaches below FCRPS projects generally support only subadult and adult bull trout rearing and/or migration. All life stages of the Kootenai River population white sturgeon occur in the Kootenai River below Libby Dam.

I.C.3.b. Total Dissolved Gas

Involuntary spill in excess of 120% may result in GBT to bull trout or their prey. Subadult and adult bull trout favor deeper waters during the daylight hours, and for this reason may be less vulnerable directly to GBT than other species. Kootenai River sturgeon also favor deeper waters, and there has been no indication of GBT affecting that population directly or indirectly through its forage base. Depending on available storage space in Kootenay Lake or the Duncan Reservoir, and operating decisions at Hugh Keenleyside Dam, releases for sturgeon or anadromous fish from Libby Dam may result in spill in the five lower Kootenay River projects in Canada. This may result in increased TDG concentrations in the Columbia River at the U.S./Canada border.

I.C.3.c. Water Temperature

Subadult and adult bull trout may persist in waters with daily highs in the 10 to 15°C range. However, the precise upper temperature threshold where bull trout subadults and adults are not harmed, either directly or indirectly, has yet to be defined. The more sensitive life stages, egg through juvenile migration ages one, two, or three, generally occur in headwater streams and require colder water, with optimum temperatures remaining below 10°C. Those projects with sufficient depth and retention time to stratify thermally may adversely or beneficially affect bull trout or sturgeon in rivers below depending upon the season, powerhouse selection, or operations of selective withdrawal facilities. Kootenai and Flathead rivers' summer water temperature has been modified for the benefit of bull trout through limited use of the selective withdrawal facilities at the Libby and Hungry Horse dams.

The opposite situation occurs with the Kootenai River population of white sturgeon. There, the spring spawning sturgeon have evolved to spawn in relative cool water, with the preferred temperature near 10°C. However, the augmentation water stored in Lake Koocanusa during the winter is frequently cooler than 10°C when needed, and its use in large volumes may delay or inhibit spawning behavior. Large volumes of water may also be needed in combination with the relatively early freshet from tributaries below Libby Dam, to maintain suitable incubation substrate, a primary constituent element of critical habitat. The only source for spring flow augmentation is the unnaturally cool water stored in Lake Koocanusa above Libby Dam, and its premature release may affect sturgeon spawning behavior. Thus, temperature is a factor in this especially challenging recovery program.

I.C.4. U.S. Army Corps of Engineers

I.C.4.a. Background

It was recognized by the Corps in the 1970s and 1980s that one of the major objectives of the CWA was to protect aquatic resources. The Corps developed a TDG monitoring program for the lower Snake and the lower Columbia rivers in the 1970s. The Corps' dissolved gas monitoring program prior to 1984 was developed to voluntarily monitor water quality. By 1984, the water quality monitoring program also provided water quality data on conditions resulting from improving anadromous fish passage at Columbia/Snake River mainstem dams. The Corps' water quality monitoring actions before the NMFS and USFWS biological opinions of the 1990s were therefore guided by both fishery agencies' resource objectives and by water quality standards objectives.

Through the 1990s, the Corps' actions for fish passage of listed species were the result of ESA consultations with the USFWS and NMFS. Consequently, the Corps' actions that affected water quality through the late 1990s were taken to comply with the ESA. Monitoring of water quality has been ongoing throughout the implementation of the biological opinions.

The chronology provided below describes the Corps' policy to comply with both the ESA and CWA. The Corps' monitoring actions before 1989 were focused on the assessment of water quality CWA. Voluntary spill actions before 1989 were considered fishery agencies' resource actions. Because of the recognition of the benefits of spill for juvenile fish passage in the late 1980s, water quality monitoring actions from 1989 to 1992 were continued by the Corps in recognition of the relationship of water quality and the protection of aquatic life. Water quality monitoring from 1992 to 2000 focused on water quality changes that were the consequence of ESA actions, i.e., voluntary spill for safer fish passage with construction of additional spillway deflectors, with a recognition that water quality may be affected. Prior to the 2000 biological opinions, one of the major water quality (CWA) actions taken by the Corps in response to the 1995 NMFS biological opinion was the Corps' Dissolved Gas Abatement Study (DGAS). Other actions included an expansion of the gas monitoring program and structural modifications, including gas abatement measures such as installation of spillway deflectors.

The 2000 NMFS biological opinion specifically identifies Reasonable and Prudent Alternative (RPA) actions 130 to 143 as water quality measures. Consequently, they can be clearly identified as actions taken for the survival of listed species that also improve water quality (CWA). Water quality strategies that benefited listed salmon were not specifically identified in earlier biological opinions.

I.C.4.b. Past Corps Actions

Between October 1990 and March 1991, Senator Hatfield's Northwest Salmon Summit resulted in a proposal to increase spill for juvenile fish passage. Sockeye salmon were listed as endangered in 1992; Snake River spring, summer, and fall chinook were listed as threatened in 1992. Also, the Northwest Power Planning Council's (NWPPC) Strategy for Salmon (1992) called for continuing spill until adequate turbine screens could be installed. This measure was included in the 1992 NMFS biological opinion. In 1992, spill for fish at the lower Snake River projects was limited to the Lower Monumental and Ice Harbor dams. As a result of the 1992 NMFS biological opinion's spill program, guided by meeting fish passage efficiencies established by NMFS, the Corps' ability to meet state water quality gas standards was affected. Additionally, the 1992 NMFS biological opinion called for releasing cool water from Dworshak Dam to cool waters for migrating juvenile salmon in August and September of each year.

Voluntary spill for juvenile fish passage was increased substantially as a result of the 1995 NMFS biological opinion to meet ESA requirements. Spill levels were calculated to obtain 80% FPE. Spill periods were for 24 hours at Ice Harbor, The Dalles, and Bonneville and 12 hours at all other lower Snake and lower Columbia River dams. Three spill caps were initiated by the 1998 NMFS biological opinion, 115% in the forebays of each project, 120% in the tailwaters, and a two-hour consecutive 125% cap at any of the lower Snake or lower Columbia River monitors.

For water temperature, the 1995 NMFS biological opinion called for releasing cool water from Dworshak Reservoir. During the1994 ESA consultation on the operation of the FCRPS, the Corps informed NMFS of its policy concerning gas water quality standards exceedances as a result of voluntary spill for fish passage. The policy was that the agency requesting spill would request a variance from the appropriate state water quality standard. NMFS made the requests for a variance from the state TDG standards from 1995 through 2000.

The 1998 NMFS supplemental biological opinion indicated that NMFS concluded that after three years of monitoring gas bubble disease, it appeared that gas levels in the range of 115 to 120% did not threaten the survival of migrating juvenile salmon and recommended spill up to the higher TDG levels (gas caps) rather than curtailing spill when 80% FPE was achieved. As a result, voluntary spill for fish passage operations were set to a spill cap rather than to a goal of FPEs at each project. Additionally, the 1998 supplemental biological opinion called for several spill-related measures at the lower Snake River and lower Columbia River dams. It called for physical hydraulic model studies of the tailrace hydraulic conditions at McNary dam and all four lower Snake River dams to develop spill patterns to achieve acceptable tailrace hydraulic conditions, both with and without additional spillway deflectors.

I.C.4.c. Dissolved Gas Abatement Study

The DGAS is an element of the Columbia River Fish Mitigation Program (CRFMP) and was initiated in 1994. It was established to examine potential methods for reducing TDG supersaturation produced by spillway operations on the eight Corps' dams on the lower Snake and Columbia rivers. The DGAS was conducted in two phases. Phase I consisted of a general investigation of alternative concepts. Phase II was a continuation of analysis and evaluations based on recommendations and study plans identified in the Phase I report. The Phase I report was published in April 1996. A Phase II 30% report was released in 1997. It identified a shift from the 110% goal to a new goal designed to reduce TDG to the extent economically, technically, and biologically feasible. A 60% report on Phase II of the DGAS was released in 1999. None of the alternatives appeared to meet both the fish passage design criteria or the 110% TDG standards up to the 7-day, 10-year high discharge event. A draft final Phase II report was distributed for review and comment in April 2001. The Corps' internal independent technical review comments are currently being addressed, after which the final report is scheduled for distribution. It is anticipated that the final report will be distributed to regional interests in the early spring of 2002.

I.C.4.d. Dissolved Gas Fast-Track (Deflector Optimization) Program

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

A Phase II 30% report was released in 1997 identifying a shift in the 110% goal to a new Corps goal to reduce TDG to the extent economically, technically, and biologically feasible. A report on the 60% report on Phase II of the DGAS was released in 1999. None of the alternatives appeared to meet the fish passage design criteria and the 110% TDG standards up to the 7-day 10-year high discharge event.

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

I.C.4.e. Water Temperature and TDG Monitoring Program

TDG and water temperature are monitored throughout the Columbia River basin using fixed monitoring stations. There are a total of 41 fixed monitoring stations in the U.S. portion of the Columbia River basin. The BOR, and the public utility districts (PUD) of Chelan and Grant Counties maintain four stations each. Two stations are maintained by the Douglas County PUD. The remaining stations are maintained by the Corps. The Northwestern Division is not responsible for the monitoring programs of the non-Corps stations. The Corps makes non-Corps data available on the TMT website in cooperation with interagency watershed management goals.

I.C.5. Bonneville Power Administration – Water Quality Projects Funded by BPA through FY2001

From the onset of the NWPPC's Fish and Wildlife Program in 1982, through FY2001, the BPA has funded projects throughout the Columbia River basin that affected water quality or contained water quality components. Most of these projects were classified as tributary habitat enhancement or watershed projects. Bonneville also funded fish production and wildlife habitat acquisition projects that included water quality monitoring components as part of an overall assessment of habitat function or impact of production activities on stream quality.

The broader definition of "water quality projects" includes: in-stream restoration activities, the monitoring and evaluation of water quality, biological or stream habitat parameters. It also includes watershed planning, research, and implementation of water quality best management practices related to agriculture, silviculture, mining, or hydro modifications. The majority of these projects occurred in tributary subbasins prioritized by the NWPPC as Model Watersheds or Focus Watersheds. Examples are the Grande Ronde, Asotin, Clearwater, John Day and Salmon River drainages. These special initiatives tended to be integrated, collaborative, and community and watershed-based.

In contrast to the tributaries, nearly all water quality projects funded on the mainstem Columbia and Snake focused on research for fish passage, survival and health. The primary water quality parameter was TDG, due to the voluntary spill program to increase fish passage and survival. Other fish survival and behavior studies in the mainstem and estuary measured temperature, dissolved oxygen, turbidity, and conductivity as they related to anadromous or resident fish. Significantly lacking were water quality projects aimed at quantifying temperature and habitat changes on an integrated basis. Most FCRPS TDG and temperature research projects have been funded by the Corps. Temperature research studies were directed at specific problems such as fish passage at specific dams. The Mid-Columbia Public Utility Districts, USGS, CRITFC and other agencies and Tribes have conducted their own water quality studies on the mainstem.

The projects listed in
Table 2 are past BPA-funded mainstem water quality activities. These projects have been in place since the year indicated in the BPA project number.

Table 2. Past (Prior to NWPPC Provincial Review Process, FY2000) BPA Funded Mainstem Water Quality Projects. The project number column contains data drawn from the CBFWA Project Finder database. The Database includes entries from 1997 to the present. Project numbering does not match the BPA numbering system.

Funding Year	Project Number	Project Title	Project Abstract
1997	9603100	Distribution of Juvenile Salmonid Populations and TDG Supersaturation in Reservoirs	Use a hydroacoustics fish stock assessment system to assess the vertical distribution of juvenile salmonids as they pass through areas of TDG supersaturation (TDGS). The prevalence of gas bubble trauma symptoms in.
1997	5501200	Improving the Effectiveness of the Gas Bubble Disease Monitoring Program on the Columbia and Snake Rivers	Improve the effectiveness of the GBD monitoring program on the Columbia and Snake rivers. Develop standardized protocols and non-lethal techniques for the examination of fish. Asses the use of physiological parameters to detect.
1997	5509200	Vertical and Horizontal Distribution of Individual Juvenile Steelhead Based on Radiotelemetry for Gas Monitoring	Project uses a miniature pressure-sensing radio tag to determine the exposure histories of individual juvenile steelhead migrating through reservoirs with high TDG. High TDG results from spill under the Biological.

Funding Year	Project Number	Project Title	Project Abstract
1999	9300802	Symptoms of GBT Induced in Salmon by TDGS of the Columbia and Snake Rivers	Study the distribution of fish in relation to TDG levels, and the resulting GBD effects on the juvenile and adult salmon of the Columbia and Snake rivers.
1998	9300802	GBT in Snake and Columbia River Salmon	Determine the relation between supersaturation levels, flow rates, fish movements, fish distribution, and GBT symptoms. Develop sample techniques, logistics, schedules, and collect preliminary data for use in design of future experiments to determine occ
1997	9300802	Symptoms of GBT Induced in Salmon by TDGS in the Snake and Columbia Rivers	Spill is provided to expedite the migration of juvenile salmon past hydroelectric dams in the Columbia River basin. However, mortality may occur during spill operations due to super-saturation of dissolved gases. Project will determine the...
2000	9602100	GBD Research and Monitoring of Juvenile Salmonids	Provide support for the Smolt Monitoring Program monitoring juvenile salmonids for signs of gas bubble disease. Activities include (1) care and maintenance of equipment, (2) training, and (3) QA/QC.
1999	9602100	GBD Research & Monitoring of Juvenile Salmonids	Conduct work on juvenile salmonids: lab studies of GBD to determine signs appropriate for monitoring; field studies of vertical and horizontal distribution of individuals to determine behavior & risk of GBD; training & QA/QC for monitoring.
1998	9602100	GBD Monitoring and Research	Provide training and QA/QC for Smolt Monitoring Program personnel examining fish for signs of GBT. II. conduct experiments to determine the progression and diminution of GBT signs in juvenile salmonids exposed to water with high TDG
1997	9602100	GBD Monitoring and Research of Juvenile Salmonids	This project is composed of a monitoring objective, a laboratory research objective and a field research objective: I. At dams and/or in-river, we will non-lethally monitor juvenile chinook and steelhead for signs of GBT. II. We will conduct...

Copies of the annual and final project reports for some of the previous TDG studies can be viewed and downloaded from the BPA Environment, Fish and Wildlife Web Page. http://www.efw.bpa.gov/cgibin/FW/publications.cgi

I.C.6. U.S. Bureau of Reclamation

Total dissolved gas levels in the Columbia River basin downstream from Grand Coulee Dam commonly exceed Washington State and Colville Tribes' water quality standard.

Exceedances are due to the combined impacts of spill operations at Grand Coulee and the downstream transfer of flow with high levels of TDG into Lake Roosevelt from spills at upstream U.S. and Canadian projects. Lower dissolved gas levels from Grand Coulee and Chief Joseph dams would reduce background TDG levels caused by these projects, which may limit the duration of exposure of fishery resources to high TDG. Further, the passage of downstream juvenile listed stocks would be improved because increased spill would be allowed at downstream projects under the revised gas cap. The 1998 NMFS biological opinion called for an investigation of operational and structural gas abatement measures at Grand Coulee and Chief Joseph dams as a part of a system-wide evaluation of gas abatement measures.

I.C.7. Columbia River Inter-Tribal Fish Commission

The Columbia River Inter-Tribal Fish Commission (CRITFC) formed in 1977 per formal resolution of the governing bodies of the four Columbia River Treaty Tribes. The four member Tribes include: The Confederated Tribes of the Warm Springs Reservation of Oregon, the Confederated Tribes and Bands of the Yakama Nation, the Confederated Tribes of the Umatilla Indian Reservation, and the Nez Perce Tribe. CRITFC is comprised of elected and appointed tribal officials who are members of the respective tribal fish and wildlife committees. CRITFC has technical and legal resources that provide assistance to the Tribes in protecting and enhancing their federally reserved trust resources.

Salmon are intrinsic to the spiritual, physical, and economic health of the four, CRITFC-member Tribes. The salmon fishery, and the waters that support it, is revered for the life and sustenance it has given and continues to provide tribal members. The mainstem Columbia River is the primary migration corridor for upper watershed spawning adults and out migrating juveniles. It also provides critical spawning, incubation and rearing habitat for salmon and other anadromous fish such as Pacific lamprey.

Today, the Columbia River and the Columbia River basin ecosystem are seriously damaged. High temperature and TDG, toxic contaminants, elevated bacteria levels, and low dissolved oxygen have impaired water quality in the mainstem Columbia in violation of state water quality standards. Poor water quality contributes to ecosystem degradation and potentially threatens the existence of salmon stocks.

The Tribal vision for the future includes a healthy Columbia River basin ecosystem characterized by clean water, complex stream systems, and interconnected habitat. *Wy-Kan-Ush-Mi Wa-Kish-Wit*, the Tribal anadromous fish restoration plan, recognizes the importance of high quality water for salmon recovery. Specifically, *Wy-Kan-Ush-Mi Wa-Kish-Wit* recommends the improvement of water quality through the elimination of toxic source contamination and the reduction of other pollutants.

II. Program Accomplishments/Results

II.A. National Marine Fisheries Service 2000 Biological Opinion

II.A.1. Reasonable and Prudent Alternatives

In developing the 2000 biological opinion, NMFS, in coordination with EPA, USFWS, and the AA, considered the respective ecological objectives of the ESA and the CWA. In many instances, actions implemented for the conservation of ESA-listed species will also move toward attainment of water quality standards (e.g., reducing TDG and temperature). The overlap of statutory purpose is extensive; however, there are additional actions that are appropriate in a water quality plan, but that are nonessential for the survival and recovery of the listed species. Thus, such actions are not required components of the ESA RPA.

Section 9.6.1.7.2 of the 2000 biological opinion serves as the nucleus of action for the development of the water quality plan called for and outlined in Appendix B of the 2000 biological opinion. The water quality action items contained in Section 9 are essential for the survival and recovery of the listed species and thus, are required components of the RPA. These actions also serve to improve water quality. The following list summarizes the water quality actions in the RPA:

1. Columbia Basin Project – Return flows from the BOR Columbia Basin Project may reduce water quality in the Columbia River and may adversely affect aquatic life and listed salmon. Because of the potential for adverse effects on listed fish, detailed water quality monitoring and analysis are needed to define these water quality effects. Depending on the results of the water quality sampling, a water quality remediation plan may be required and implemented. The results of the Columbia Basin Project water quality characterization will be included in the AA's water quality program and implementation plans. The implementing agency will be the BOR.
2. Corps DGAS Program – The feasibility-level DGAS report was completed in 2001. The findings from this study have to be examined and discussed with interested parties in the region to guide future studies before making long-term implementation decisions about gas abatement alternatives. For more information see the Corps discussion of DGAS below in Section II.D.5. The implementing agency will be the Corps.
3. TDG Monitoring – The physical monitoring of TDG associated with implementation of the biological opinion spill program includes placement of TDG monitors in the tailraces and forebays of all lower Snake River and lower Columbia River dams, and daily data reporting of TDG on the CROHMS database during the juvenile migration season. The biological components of the monitoring program will include adult and smolt monitoring at selected locations and daily data collection and recording. The implementing agency will be the Corps.
4. Review of TDG Fixed Monitoring Stations – Inseason management of biological opinion spill to improve juvenile fish survival relies on the physical TDG and the Smolt Monitoring Programs. In past years, TDG monitoring in tailraces at mainstem dams produced variable results associated with differences in dam operations. NMFS

believes some sampling locations may have to be altered in order to provide a more representative measure of TDG in the water mass passing through the dams. The implementing agency will be the Corps.

5. Dissolved Gas Model – Since the 1960s, increased hydraulic capacity at powerhouses of mainstem projects, increased water storage and structural modification to spillways have substantially reduced TDG. High levels of dissolved gas have been measured under some river conditions even in recent years, such as during periods of involuntary spill. Development and continued refinement of a systemwide TDG model would assist with in-season management of spill. The implementing agency will be the Corps.
6. Spillway Deflector Optimization Program – The Corps is continuing the spillway deflector optimization program at each FCRPS project and implementing modifications as warranted. The program addresses physical and biological evaluations to ensure optimum gas abatement and fish passage conditions. Implementation decisions are based on the effect of spill duration and the volume of TDG, spillway effectiveness, spill efficiency, forebay residence time, and total project and system survival of juvenile salmon and steelhead passing FCRPS dams. The implementing agency will be the Corps.
7. Tailrace Divider Walls – Depending on spill and powerhouse discharge flow dynamics a portion of the powerhouse water may be entrained in the spillway flow. The powerhouse waters are then subject to additions of dissolved gas. The degree to which powerhouse flow in the tailrace mixes laterally with spillway flow is an unresolved issue. Additional investigation is required to increase understanding of this issue prior to pursuit of corrective actions. The implementing agency will be the Corps.
8. Grand Coulee/Chief Joseph Gas Abatement Planning – To the extent feasible, The AAs will treat the Grand Coulee and Chief Joseph dams as a composite project to reduce the incidence of spill and TDG below Grand Coulee. Fulfillment of this action requires installation of spillway deflectors at Chief Joseph dam. This modification failed to receive Congressional funding in FY2002, thus delaying the water quality benefit of lowered TDG in the upper and middle Columbia River reaches. The implementing agency will be the Corps.
9. Libby Dam Gas Abatement – Spill at Libby dam has two negative effects: increased dissolved gas downstream and reduced probability of refill if spill occurs. The Corps is to assess projected gas abatement options and site-specific and systemwide effects of implementing gas abatement measures. The implementing agency will be the Corps.
10. Removable Spillway Weirs (RSW) – Surface bypass concepts, e.g., RSW have the potential of reducing both spill discharge and TDG levels downstream, yet improving passage of adult steelhead kelts and juvenile migrants. The implementing agency will be the Corps.
11. Dworshak Gas Abatement – Implementation of TDG abatement measures at Dworshak has the potential to improve water quality when project discharges exceed current turbine capacity. Options may include increasing the number of turbine units at the powerhouse. The implementing agency will be the Corps.

12. John Day Spillway 1 Deflector – Absence of a spillway deflector at spill bay Number 1 results in fixed monitor station TDG readings that are unrepresentative relative to the entire tailrace. The implementing agency will be the Corps.
13. Water Temperature, Fish Disease and Thermal Stress – High water temperatures have been linked to stress and disease in fish. It is essential to acquire a better base of information to understand the sources of fish disease and mortality at the lower Columbia and lower Snake river dams during critical fish migration periods and high temperature events. This information could be used to better understand the effect of high water temperature on juvenile fish survival. The implementing agencies will be the Corps and BPA.
14. Lethal Thermal Stress to Juvenile Fish at McNary Dam – The Corps will analyze temperature data that have been recorded in the McNary forebay, collection channel, and juvenile facilities to reveal relationships between juvenile mortality, temperatures, river flow rates, and unit operations. The Corps will evaluate the potential for optimized performance operations or structural modifications in order to minimize thermal stress to juvenile migrants at McNary dam. The implementing agency will be the Corps.
15. Water Temperature Monitoring and Models – The AAs will develop a plan to model the water temperature effects of alternative Snake River operations. The plan is to include a temperature data collection strategy sufficient to operate a model, and to document the effects of project operations. The implementing agencies will be the Corps and BPA.

II.A.2. Mainstem System Water Quality Plan

The ESA and the CWA are complementary statutes offering opportunities to conserve listed species and improve overall system water quality. Both laws stress the importance of maintaining ecosystem integrity. Recognizing these facts, EPA, NMFS, USFWS, and the AA intend to integrate their fish and wildlife and water quality efforts in the form of actions to support the objectives and responsibilities of the ESA, CWA, and other fish, wildlife and water quality statutes such as the Northwest Electric Power Planning and Conservation Act. Over the long term, with a focus on water quality, the regional entities have committed to developing and implementing a water quality plan that supports TDG and temperature water quality improvements to the Columbia River basin. The mainstem system water quality plan is anticipated to be consistent with the Columbia River and Snake River mainstem TMDL limits that are currently being developed by EPA, the states, and the Tribes. Water quality plan implementation anticipates that EPA, NMFS, and the AA will properly integrate implementation of the plan with ongoing TMDL development activities on the mainstem and in the subbasins.

To successfully implement the mainstem system water quality plan for the FCRPS, a coalition of Federal, state, Tribal, and other appropriate regional representatives is necessary to integrate the efforts of all interested stakeholders and provide a connection with ongoing, broad-scale coordination efforts in the basin. These include planning and review processes of the NWPPC, which includes the Independent Scientific Review Panel, the Columbia Basin Fish and Wildlife Authority (CBFWA), and the NMFS Regional Forum. Some measures may also require congressional approval. NMFS, EPA, USFWS, and the AA intend to support implementation of measures that successfully garner approval through these processes. A common approach for selecting which water quality, ESA, and fish and wildlife measures for implementation will foster coordination among NMFS, EPA, and the AA, and will increase the effective use of limited available resources. The outcome of this coordinated approach will be a collection of measures the AA undertake in order to serve the agencies' various statutory purposes within budgetary parameters. Recommendations approved via applicable processes could be identified in the water quality plan for implementation.

The mainstem system water quality plan is likely to require lengthy study and implementation exceeding the duration of the NMFS 2000 biological opinion. Accordingly, action items already in the RPA for the FCRPS form the nucleus of actions for the water quality plan. These actions are essential for the survival and recovery of the listed species and thus are required components of the RPA.

II.B. Environmental Protection Agency Total Maximum Daily Loads

II.B.1. Environmental Protection Agency Total Maximum Daily Loads

The most recent 303(d) Lists were developed in 1998. Segments of the Columbia River were listed on the Washington and Oregon list for TDG, temperature, arsenic, bacteria, bis(2-ethylhexyl) phthalate, DDT/DDE dieldrin, dissolved oxygen, mercury, PCBs, pH, sediment bioassay, and water column bioassay. Segments of the Snake River below the Hells Canyon Dam are listed for TDG, temperature, dissolved oxygen and mercury (Table 1). Much of the data for chemical constituents was collected from fish tissue or bottom sediment samples.

Several TMDLs are currently under development for the mainstem Columbia and Snake rivers. The states of Idaho and Oregon are currently developing TMDLs for all 303(d) listings on the Snake River between Hells Canyon Dam and the confluence of the Salmon River. In addition, the states of Oregon and Washington are currently developing a TMDL for TDG for the lower Columbia River (from the confluence of the Snake River to the Pacific Ocean) and a draft TMDL is expected to be released shortly. These TMDLs are expected to be finalized in the first quarter of 2002.

The state of Washington and EPA, in coordination with the Spokane and Colville Tribes, are initiating the development of a TDG TMDL for the Columbia River between the Canadian border and the confluence of the Snake River. The state of Washington is also commencing a similar effort on the Snake River between the Idaho/Washington border and the Columbia River. These TMDLs are expected to be completed by the end of 2002.

The states of Idaho, Oregon and Washington and EPA, in coordination with the Columbia Basin Tribes, are working to develop a temperature TMDL for the Columbia River from the Canadian border to the Pacific Ocean, and for the Snake River from the Salmon River to its confluence with the Columbia. Much of the technical work for this TMDL is completed and a draft is expected to be released shortly. The TMDL is expected to be completed by the end of 2002.

In addition, EPA and the state of Oregon are currently evaluating other pollutant listings in the lower Columbia River (below the Washington/Oregon border). Monitoring conducted during the summer of 2001 should provide information on the geographic scope of the dissolved oxygen and bacteria listings. TMDLs for these pollutants are likely to be developed by the state of Oregon in 2002. TMDLs for toxic contaminates should also be developed in the next two to three years, although exact dates have yet to be determined.

II.B.2. Lower Columbia Draft TDG TMDL

The draft TDG TMDL document prepared by the states of Oregon and Washington describes the production of TDG at each of the four Federal hydropower projects in the lower Columbia River. General production equations are presented, and specific equations taking into account the particular physical characteristics of each of the four projects are presented.

Load allocations are presented for each of the four projects. Given the clear mathematical relationship between spill quantity and TDG, load allocations will be specified as the delta TDG pressure (ΔP) at each of the projects. The ΔP is defined by the difference between the TDG pressure in the water and the local barometric pressure.

An Implementation Plan is included and incorporates actions described and analyzed by NMFS in its 2000 biological opinion and by the Corps in its Dissolved Gas Abatement Study. Both short-term and long-term measures are described along with estimates of gas abatement and implementation costs and schedules.

II.B.3. EPA Pacific Northwest Water Temperature Criteria Guidance Project

Cold, clean water is critical to the protection of threatened and endangered salmon, steelhead, bull trout and cutthroat trout (salmonids). These fish need cold water throughout their various life stages and appropriate water temperature is a critical part of their habitat. Temperature in rivers and streams varies with the seasons, as well as over the course of 24 hours and over the length of a river. A water quality standard for temperature is key to ensuring rivers and streams are cold enough to support these fish.

In 1996, Oregon revised its water temperature standard and submitted it to EPA for approval. During the ESA review prior to EPA's approval of the standard in 1999, concerns were identified by EPA, NMFS, USFWS and others that this standard would not fully protect all life stages of threatened and endangered salmonids. In order to address these concerns, after EPA's approval of the standard, EPA Region 10 started a project to develop regional temperature criteria guidance that would be fully protective of salmonids. This Regional Temperature Criteria Guidance will supplement the national water quality criteria for temperature to meet the specific needs of salmonids in Northwest streams and rivers.

A technical work group, made up of experts from the three states, Pacific Northwest Tribes and Federal Agencies, has produced five Technical Issue Summaries covering key scientific aspects relating to water temperature and salmonids, as well as creating an overall Synthesis Paper. The specific topics covered in the Summaries are: physiological responses of salmonids to temperature, behavioral responses, the effects of multiple stressors on salmonids (for example, the effects of predators), the geographical distribution of salmonid species, and the patterns of temperature fluctuations in the natural environment. These Summaries, plus a Synthesis Paper lay the scientific foundation upon which the regional criteria guidance will be built. The full, peer-reviewed text of the Technical Issue Summaries, as well as the overall Synthesis Paper, are available on EPA's website: www.epa.gov/r10earth/water.htm

In addition to the technical work group's efforts to build a solid, scientific foundation for the Temperature Criteria Guidance, a policy work group has also been laying the groundwork for the project by setting clear goals and establishing expected outcomes. This work group is made up of managers from the three states, the Services, the Tribes and EPA. This policy work group is primarily focusing on making the Guidance practical and making sure it complies with the CWA, the ESA, and the Tribal Trust responsibilities.

To date, the work of the Regional Temperature Criteria Guidance Project has been largely focused on pulling together and analyzing the most current and relevant scientific information related to water temperature and its effect on native salmonids of the Pacific Northwest.

The overall goal of the Regional Temperature Criteria Guidance Project is for the states and Tribes of the Pacific Northwest to use this Guidance when developing their temperature standards. Ultimately, if the states and Tribes adopt the regional criteria as water quality standards, EPA Region 10 will approve those standards as meeting the CWA and will be able to conduct a streamlined ESA consultation for their standards. States and Tribes, however, will still be able to adopt a temperature standard different than the Regional Criteria Guidance, but they will have to demonstrate it meets the CWA and the ESA.

II.C. U.S. Fish and Wildlife Service Biological Opinion

II.C.1. Reasonable and Prudent Alternatives

Studies of the possible effects of TDG supersaturation have been recommended for the Libby Project to determine if small increments of increased release capacity for sturgeon flow augmentation can be achieved by using the spillways at the Libby Project within the state of Montana's CWA criterion of 110% TDG. Because of drought and power emergencies during 2001, this study was postponed until spring 2002. During the fall of 2001 the Corps initiated scoping in anticipation of completing an Environmental Impact Statement during 2004 which will address possible impacts of TDG on bull trout and other species in the Kootenai River from the use of the spillways at Libby Dam.

Under the 2000 NMFS FCRPS Biological Opinion, the selective withdrawal facility at the Libby Project continues to be operated to modify spawning/incubation temperatures for sturgeon.

II.C.2. Incidental Take

Prior to developing specific recommendations for gas abatement for bull trout, USFWS is now seeking information, through the AA's studies, on the status of bull trout and their use of the lower Columbia and Snake rivers. The gas abatement studies of flow deflectors at the John Day Dam have been identified as a likely approach if it is determined that TDG may harm bull trout in the lower Columbia or Snake rivers .

As part of the proposed action in the December 19, 2000 supplement to FCRPS biological assessment, operations at both the Hungry Horse and Libby dams utilize the selective withdrawal systems to approximate natural summer water temperatures in the range of 8 to12°C in the rivers below these projects for bull trout.

II.D. U.S. Army Corps of Engineers

II.D.1. Spill Temporary TDG Standard Waiver Process

One of the components of the 2000 NMFS biological opinion water quality strategy was for the Corps to take the actions necessary to implement spill operations at the dams called for in the biological opinion, including obtaining variances from the appropriate water quality standards. The Corps coordinated these actions with the state water quality agencies for the 2001 spill season and has begun actions for the 2002 spill season.

As a long-term strategy, the Corps opened discussions about the process of pursuing long-term variances from the entities involved, hoping to eventually replace the year-to-year processes. Meetings with the states and Tribes were held in the spring and summer of 2001 to begin discussions. Further meetings will be held in 2002, to continue discussions to obtain long-term variances.

In the interim, as long-term variances are being explored, the Corps pursued the following actions in 2001 to obtain variances from the states of Idaho, Oregon, and Washington. The state of Idaho was approached concerning a variance to water quality standards. The state, in conjunction with the Nez Perce Tribe, provided a set of conditions as part of the variance process. Due to these conditions provided by the state and the Tribe, the forecasted drought conditions and the foreseen use of Dworshak water releases, there was no further pursuit of a water quality variance by the Corps for the 2001 water year. Idaho state water quality standards were generally met.

The Oregon Environmental Quality Commission (OEQ Commission) met on March 30, 2001, and issued a variance for the 2001 spill season, subject to specific conditions, as signed by Director Stephanie Hallock on May 5, 2001. A variance of the TDG standard for the Columbia River was provided from midnight on April 10, 2001, to midnight August 31, 2001. The OEQ Commission approved a TDG standard for the Columbia River of a daily (12 highest hours) average of 115% as measured in the forebays of McNary, John Day, The Dalles, and Bonneville dams, and at the Camas/Washougal monitoring stations. They approved a cap on TDG for the Columbia River during the spill program of 120% as measured at the McNary, John Day, The Dalles, and Bonneville dams tailwater monitoring stations, similarly based on the average of the 12 highest hourly measurements per calendar day. The OEQ Commission also approved a cap on TDG for the Columbia River during the spill program of 125%, based on the highest two hours per calendar day. The OEQ Commission also required that if 15% of the juvenile fish examined showed signs of gas bubble disease in their non-paired fins, where more than 25% of the surface area of the fin was occluded by gas bubbles, the variance would be terminated.

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

In the past, the state of Washington modified its TDG water quality standard on a long-term basis, which remains in effect through the 2002 water year. Therefore, additional actions with the state were not required for the 2001 water year.

II.D.2. DGAS Program Results

The Phase I report was published in April 1996. A draft final Phase II report was distributed for review and comment in April 2001. Corps internal independent technical review comments are currently being addressed. The final report is scheduled for distribution as soon as the technical review comments are addressed. It is anticipated that the changes will be minor and that the final will be distributed to regional interest in the early spring of 2002. This report is being utilized as informational material by the states of Oregon and Washington for development of TDG TMDLs and associated implementation plans.

II.D.3. Gas Abatement Fast-Track Deflector Optimization Program

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

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

Project	Pre-1995 Number of Spillways with Deflectors	Post-2003 Number of Deflectors	Total Number of Spillways
Bonneville	13	18	18
The Dalles	SIS[1]	SIS[1]	22
John Day	0	18	20
McNary	18	22	22
Ice Harbor	0	10	10
Lower Monumental	6	8	8
Little Goose	6	8	8
Lower Granite	8	8	8

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

II.D.3.a. Bonneville Dam

Deflectors were constructed on 13 of the 18 spillways in the early 1970s. These deflectors were designed for involuntary spillway releases, which occur when river discharges exceed powerhouse capacities or power demand. Because of the shift from involuntary to voluntary spill for fish passage, TDG supersaturation during spillway operation has again become a regional concern. At Bonneville, five additional deflectors are to be added in bays 1, 2, 3, 16, and 17, and at bay 18, the existing deflector must be removed and replaced. These deflectors will be installed about seven feet lower than where the existing deflectors are located. Revised spill patterns will be established for the new configuration. After installation of the new deflectors, the Corps will conduct comparative tests to determine whether or not the new deflectors perform significantly better than the existing deflectors do. A decision document will be prepared to document the findings and assist the region in deciding whether or not additional deflectors should be modified.

Construction work in bays 1, 2, 3, 16, 17, and 18 was initiated in late 2001 and will be complete for the fish passage season of 2002. A post-construction evaluation (biological) test in spring and late summer. Near field TDG testing to determine effectiveness of the new flow deflectors also will be conducted. A decision will be made in early 2003 as to whether replacement of the existing deflectors is warranted. If replacement is deemed appropriate, construction contract preparation will be initiated and the 2nd phase of construction is scheduled to be completed by 2005.

II.D.3.b. The Dalles Dam

The Dalles was not identified as a project for immediate implementation of spillway flow deflectors at the conclusion of the DGAS Phase I, primarily due to its relatively shallow stilling basin. Deflectors may still significantly reduce TDG at The Dalles, however, and are being considered as one component of a Spillway Improvement Study (SIS) underway, which will analyze various spillway improvements at The Dalles designed to improve juvenile survival through the spillway passage route. The study was initiated due to the relatively high spillway juvenile mortality measured at The Dalles during high spill volumes in recent years.

The SIS will rely heavily on numeric and hydraulic modeling efforts, which are anticipated to provide hydrodynamic data to help define the optimum deflector design elevation for TDG abatement. Due to the complexity of the stilling basin hydrodynamics and downstream topography, deflector benefits of reduced TDG may be offset by increased juvenile predation, direct impact or other factors that may be influenced by the deflected flow pattern. These factors require full analysis and understanding prior to implementation.

II.D.3.c. John Day Dam

As indicated above, 18 of the 20 spillway bays at John Day were modified with flow deflectors in February 1998. New spill patterns were established at that time. End bays (bays 1 and 20) were not modified due to concerns with adverse adult entrance conditions with deflectors on these bays. Subsequently, the additional increment of improvement in gas entrainment during involuntary spill conditions prompted reconsideration of deflector installation on the end bays. Also under consideration is an extended flow deflector on Bay

20 which would potentially be installed in association with a surface bypass weir (a removable spillway weir) prototype for testing at that bay. The RSW prototype program at John Day is presently deferred to address potential adverse effects of its operation on juvenile fish egress from the stilling basin. Until that issue is resolved, end-bay flow deflector installation is on hold.

II.D.3.d. McNary Dam

Physical hydraulic model studies of the tailrace hydraulic conditions at McNary have been conducted to allow development of new spill patterns to achieve acceptable tailrace hydraulic conditions for both adult fish passage and juvenile fish egress from the tailrace area. Deflector improvements combined with changes in spill patterns will provide benefits in reduced TDG during involuntary spill events. The McNary spillway consists of 22 spillway bays. Twenty-one spillway bays are operational. Eighteen spillway bays have deflectors. Modifications include adding deflectors to spillway bays 1, 2, 21, and 22. Other modifications include lengthening an existing training wall to protect an adjacent fish ladder entrance on the North Shore from adverse hydraulic conditions. In addition, design is proceeding on a training wall extension to protect an adjacent fish ladder entrance on the North Shore from adverse hydraulic conditions. The adverse hydraulic conditions are created by operation of adjacent spillway bays with deflectors. The effect of a powerhouse/spillway divider wall will also be investigated as a possible future measure to reduce TDG beyond that achievable by deflectors. A post-deflector construction TDG field study is also planned for the spring of FY2002.

II.D.3.e. Lower Monumental Dam

Deflectors exist on six of the eight spillway bays at Lower Monumental. Modifications to reduce TDG production include the addition of deflectors to spillway bays 1 and 8. A spillway/powerhouse divider wall will also be examined as a possible improvement. Engineering work began on this project in FY1999. The new endbay deflectors should be completed by March 2003. A post deflector construction field test will be conducted to assess performance improvements in the spring.

II.D.3.f. Little Goose Dam

Deflectors currently exist on six of the eight spillway bays at Little Goose. Possible modifications include the addition of deflectors to end bays 1 and 8, adding radius transitions and pier nose extensions to the existing deflectors and possibly extending the deflector length. Construction is anticipated for completion by March 2003. Consideration may also be given to relocating the deflectors at an elevation optimized for current operation. A spillway/powerhouse divider wall will also be examined.

II.D.4. Adult Fish Ladder Temperature Study

This project is in response to the 2000 NMFS biological opinion Action 114, which states: “The Corps shall examine existing fish-ladder water temperature and adult radio-telemetry data to determine whether observed temperature differences in fishways adversely affect fish passage time and holding behavior. If non-uniform temperatures are found to cause delay, means for supplying cooler water to identified areas of warmer temperatures should be developed and implemented in coordination with the annual planning process."

There is evidence that indicates temperature gradients elicit a behavioral response in adult steelhead and, to some extent, adult chinook salmon. This is demonstrated by the interruption of adult steelhead and chinook salmon migration in response to temperature differences at the confluence of the Snake and Columbia rivers. During mid-summer, when the Snake River warms more quickly than the Columbia River, and river temperatures are nearing the lethal limit for salmonids, some steelhead and chinook salmon hold for several weeks in the Columbia River. They enter the Snake River after temperatures have started to decline and the temperatures of the two rivers converge. This holding behavior is seen again as steelhead approach the confluence of the Clearwater River. In addition, several fish passage delays have been reported during temperature differences near adult fishways. Temperature differences of a few degrees at the confluence of the lower Columbia and Snake rivers and at fishways at other dams have caused adults to delay; it is logical to assume adults may behave in a similar manner when they encounter a temperature difference in or near the lower Snake River adult fishways. In addition, several occurrences of fish passage delays caused by temperature differences near adult fishways has been observed. Sockeye and steelhead passage was reduced at a Columbia River fishway that was heated to temperatures 4°C above the ambient river temperatures. A similar temperature blockage has been reported at the Pelton Dam on the Deschutes River (Oregon) during the summer when temperature differences ranged between 6-8°C.

Temperature data collected in the adult fishways have shown differences occur between the fish ladders and the tailrace temperatures. In general, these temperature differences are less than 2°C. However, during late summer in years of warm weather and low flows, a temperature difference of greater than 2°C can occur. To date, the largest temperature difference recorded is 4.5°C in 1992, at Lower Granite. If temperature differences of a few degrees at the confluence of the Snake and Columbia rivers and at fishways at other dams may cause adults to delay, it is logical to assume adults may behave in a similar manner when they encounter a temperature difference in or near the lower Snake River adult fishways. This Corps project will attempt to collect and compile all known existing temperature data for the area of interest. The data will be reviewed for quality, compiled into a database and analyzed.

A Phase I technical report of a potentially multi-phased effort was initiated in 2001. A draft report has been submitted to the Fish Facility Design and Review Work Group (FFDRWG) for review and comment. The report will include compilation of existing temperature data, data analysis and reporting. Depending on results of the Phase I effort, additional work (both biological and physical) may be necessary. The long-term objective of this potentially multi-phased project is to define any problems that may exist specific to effects of fish ladder water temperature on adult salmon and steelhead and to determine feasible methods of mitigating any adverse affects.

II.D.5. McNary Forebay Temperature Study

The McNary Forebay Temperature Study is scheduled for 2001/2002. During summer months, water temperature in the McNary forebay, gatewells, and fish collection channel can be stressful to migrants. Water temperatures in the south end of the forebay can be elevated

significantly compared to the rest of the forebay. This results in warmer water being drawn into the adjacent gatewells. Juvenile salmonids that enter these gatewells (units 1-4) may be subject to rapid changes in water temperatures that may be stressful or possibly lethal. This ongoing project will examine potential methods (both structural and operational) to alleviate or minimize the water
temperature gradients which can develop in the McNary forebay and gatewells during the summer months.

Efforts to date have included changes in powerhouse operations, but have only been partially successful, and have not made an impact on temperatures in the forebay. In anticipation of high summer water temperatures in 2001, flow "mixers" were installed in the forebay. The purpose of the mixers is to attempt to break up the vertical temperature stratification. The intent is to mix cooler water from the forebay with the warm lens that develops in the cul-de-sac at the south end of the powerhouse. This warm water lens occurs every summer, but it is worse in low flow/high temperature years. Initial testing/monitoring was performed in the summer of 2001 to address immediate concerns, however, long-term/permanent solutions must be designed.
A computational fluid dynamics model will be developed to assess the current temperature problem and assist in evaluating potential structural and operational solutions. This task may include significant data collection for both model development and verification. Alternatives will be developed in a regional coordination process after significant progress has been made in defining the problem. Analysis of alternatives may be completed using both numerical and physical models. A technical report will be prepared to assist in developing recommendations for future study or application. This will include analysis of alternatives, recommendations for further investigations, and costs of alternatives.

II.D.6. Seattle District, Chief Joseph Deflectors

The 2000 NMFS FCRPS Biological Opinion required the Corps and BOR to individually and jointly examine gas abatement opportunities at Chief Joseph and Grand Coulee dams. The Corps initiated a planning study for Chief Joseph Dam. Similarly, the BOR began an evaluation of alternatives for Grand Coulee (See II.F.1.). The Corps and BOR also began a study of joint operation to reduce TDG loading into the Columbia.

The Corps conducted several phases of study and produced several documents that can be found on the Web: http://www.nwd-wc.usace.army.mil/nws/hh/gas/index.html

The Initial Appraisal Report examined 19 alternatives and recommended nine for further study. These nine were further screened to three alternatives. The System Configuration Team (SCT) participated in this screening process. A near-field TDG test was conducted in June 1999. The System Total Dissolved Gas (SYSTDG) model was initially a product of the joint study alternative which was addressed in the General Reevaluation Report, a feasibility level document. The preferred alternative was to install flow deflectors at Chief Joseph Dam and to operate it jointly with Grand Coulee. Joint operation would entail a shifting of spill from Grand Coulee to Chief Joseph and a shifting of generation in the opposite direction.

II.E. Bonneville Power Administration

Table 4 lists ongoing mainstem/systemwide water quality projects recommended in the NWPPC's provisional start-of-year budget for FY2002, approved at the NWPPC's September 27, 2001, meeting in Spokane and documented in an October 19, 2001, letter to BPA. Also listed in the table are mainstem water quality projects that were considered in the process but were not selected for funding. Although these projects did not receive NWPPC approval for funding, the subject matter revealed in the table abstracts gives an indication of water quality topics that were submitted by proposers. Additional projects may be selected after the upcoming mainstem/systemwide Province solicitation for FY2003 funding.

Table 4. Mainstem Water Quality Projects Submitted During the NWPPC Provincial Review Process (FY2000 to the present). The project number column contains data drawn from the CBFWA Project Finder database. The Project numbering does not match the BPA numbering system.

A. BPA Funded Projects

Funding Year	Project Number	Project Title	Project Abstract
2002	25049	Numerically Simulating the Hydrodynamic and Water Quality Environment for Migrating Salmon in the Lower Snake River	The objective of this work is to apply state-of-the-art computer models that can describe the complex hydrodynamic and water quality environment in the lower Snake River, and to relate that information to migrating salmon.
2001	22059	Using LIDAR technology for improved riparian vegetation monitoring and stream system water temperature modeling and TMDL development	Project is oriented to high quality, geographically extensive, riparian tree data acquisition allowing efficient water temperature modeling and analysis of riparian tree height and cover, key fish habitat quality parameters. Systemwide Province project. Target species=all salmon.
2003	29039	The effects of fine sediment on the hyporheic zone: monitoring and evaluating the influence of hyporheic exchange flows on stream temperature	Implement sediment and temperature monitoring; research to evaluate the influence of hyporheic exchange flows on stream temperature and thermal refugia; research to evaluate the influence of fine sediment on the hyporheic zone. Project location is the Wenatchee River Subbasin. However, the research results may have systemwide and mainstem applications.
2001	199602100	Gas bubble disease research and monitoring of juvenile salmonids	Provide support for the Smolt Monitoring Program (SMP) monitoring juvenile salmonids for signs of gas bubble disease. Activities include (1) care and maintenance of equipment, (2) training, and (3) QA/QC.

B. Projects Submitted but Unfunded

Funding Year	Project Number	Project Title	Project Abstract
2000	20110	Develop Wheels, Pools and Falls Approach for Fish Passage at Dams	Conduct an Environmental Science Analysis using the Wheels, Pools, and Falls approach to transform the dam spillways into a series of pools and falls designed for continuous safe passage in water deemed safe by water quality standards for all aquatics.

II.F. U.S. Bureau of Reclamation

II.F.1. Grand Coulee Gas Management Study

The BOR completed the "Structural Alternatives for TDG Abatement at Grand Coulee Dam" in October 2000. The study of gas abatement options at Grand Coulee Dam was conducted on a parallel track with Corps studies of Chief Joseph Dam spillway deflectors (II.D.6.). The study evaluated gas abatement effects in the Grand Coulee tailrace with and without transfer of power loads from Chief Joseph to Grand Coulee. Results of the BOR study indicate that the ability to reach 110% TDG in the river below Grand Coulee is more dependent on the TDG levels present in the reservoir than on any of the structural or operational changes studied. A potential structural gas abatement option at Grand Coulee is to extend and cover the existing outlet tubes to provide for submerged discharge of spill.

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

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

II.F.2. Columbia Basin Project Wasteway Return Water Quality Study

In response to the NMFS 2000 biological opinion, the BOR, and the Columbia Basin Irrigation Districts have initiated a 5-year water quality study of Columbia Basin Project irrigation return flows. The study is designed to characterize project return flow water quality, and identify potential biological impacts to ESA listed species. If significant deleterious impacts are identified in the study, appropriate abatement strategies will be developed and implemented. A return flow water quality characterization and monitoring plan proposal was prepared by the BOR in June, 2001. Data gathering will be initiated in the 2002 water delivery season.

II.G. Columbia River Inter-Tribal Fish Commission Mainstem Water Quality Accomplishments

The role of CRITFC is to assist its member Tribes in the management of their treaty-reserved resources. To fulfill this responsibility, CRITFC participates on numerous Columbia River basin water quality forums. As co-managers of the salmon resource, CRITFC and the member Tribes continue to pursue several approaches to address the very important and often-difficult water quality issues of the mainstem Columbia River. For example, CRTIFC has taken the initiative to pursue several regional water quality issues including TDG, temperature and toxic contaminants. This participation is described below.

II.G.1. Mainstem Columbia River TMDL Process

II.G.1.a. Columbia River Water Quality Conference

The 2001 Columbia River Basin Tribal Water Quality Conference was held September 26-28 at the Kah-Nee-Ta Resort on the Warm Springs Reservation. The conference provided a forum for discussion and technical exchange on a variety of water quality issues that affect tribal water resources in the Columbia River basin. The event was well-attended and included representatives from 15 Tribal governments, several Federal and state resource agency personnel and other organizations. Water quality topics addressed at the conference included:

1. Development of a Tribal vision for water quality,
2. Development of the mainstem Columbia River TMDLs for TDG and temperature, and
3. Improvement of communication between the Tribes and Federal and state agencies.

Facilitated sessions held during the conference provided an opportunity for in-depth discussion on these topics. These discussions identified several areas for further consideration and development.

1. Development of Tribal water quality management strategies for salmon restoration,
2. Development of fish and human health initiatives,
3. Continued communication among the Columbia River basin Tribes and the state and Federal agencies;
4. Establishment of a CRITFC TMDL team to address TMDL development on the mainstem Columbia River for temperature and TDG, and
5. Continued tribal outreach on technical and policy issues related to the TMDL process.

Summaries of the facilitated sessions and each conference presentation have been compiled in the conference proceedings for distribution to the conference participants.

II.G.1.b. Mainstem Columbia River TDG Workshop

In response to the future needs identified at the 2001 Columbia River Basin Tribal Water Quality Conference, the CRITFC TMDL Team hosted a one-day technical workshop on the TDG TMDL. The purpose of this workshop was for Tribal technical staff to discuss the TDG TMDL with staff from EPA, the ODEQ, and the Washington Department of Ecology (WDOE). Tribal representatives included the Nez Perce Tribe, the Yakama Nation, and the Colville Tribe.

Several topics related to this TDG TMDL process were discussed including the relationship between fish passage spill and water quality standards, potential structural modification of the dams to reduce TDG, gas bubble trauma disease, state and EPA CWA authorities, and the TMDL process vs. the Implementation Plan.

One area of concern is how to integrate fish passage programs, and CWA and ESA mandates. Because the TDG TMDL is a CWA action, it is being conducted within the framework of the CWA. The TDG TMDL focus, therefore, is on the properties of the water column (i.e., TDG water quality) that impact the CWA-designated beneficial uses. Accordingly, TDG levels for the TDG TMDL will be based on the current numeric criteria of 110% for TDG. Pursuant to ESA, however, the NMFS hydrosystem biological opinion has set the baseline for the spill waivers at 115-120% for TDG. These two obligations have created a situation with apparently conflicting performance standards.

In *Wy-Kan-Ush-Mi Wa-Kish-Wit*, and in formal comments on water quality standard waivers for salmon spill, CRITFC and its member Tribes have supported temporarily increasing TDG levels to 125% TDG in order to meet fish passage efficiency standards of 80-90%. This level would be maintained until structural changes are implemented to reduce the TDG levels towards the current criteria. In studies conducted by CRITFC and the Federal fishery agencies, a lower risk of salmon mortality was observed for fish passage through spill at high TDG levels compared to fish passage through turbines and screen bypass systems.

The TDG Implementation Plan will be a phased approach with short- and long-term water quality goals. In the short term (i.e., the next 10 years), the current water quality standard of 110% for TDG will not be attained. During this 10-year period, however, it is imperative that Federal hydropower systems implement step-wise structural modifications of the dams that will bring TDG into compliance (except during flood flow conditions) with state water quality standards in the long term.

II.G.2. EPA Region 10 Temperature Criteria Guidance Project

As mentioned earlier in the document (see EPA Discussion this section), this process has been a collaborative effort between EPA, the states, the Services, and Pacific Northwest Tribes. Involvement in this process by the CRITFC member Tribes is important to meeting the goals and objectives of their Tribal restoration program. Tribal participation, however, has been limited to CRITFC (policy and technical teams) and the Nez Perce Tribe (policy team). As a result, discussions on key elements of the guidance represent a narrow view of Tribal concerns regarding temperature and salmon. Moreover, formal consultation with the CRITFC-member Tribes has not yet occurred. Tribal outreach, funding for Tribal participation, and government-to-government consultation on this and other mainstem Columbia River water quality issues and processes is imperative to ensure meaningful participation by the member Tribes.

II.G.3. Columbia River Basin Fish Contaminant Survey

EPA is completing a fish tissue chemical contaminant study for the Columbia River basin. This study is part of a three-part process to assess the impacts to fish and human health from exposure to toxic contaminants found in the Columbia River basin. In 1991, CRITFC and EPA entered into a cooperative agreement to conduct a fish consumption survey of the

CRITFC member Tribes (Phase I). The fish consumption survey, completed in 1994, found that the mean rate of fish consumption for adult CRITFC tribal members was approximately 10 times higher than that of the non-Tribal community.

Phase II of this cooperative agreement was initiated in 1996. The study had two objectives:

1. To measure fish contaminant levels for species and fishing locations being utilized by CRITFC member Tribes, and
2. To estimate potential health effects to people who eat fish caught in the Columbia River basin.

From 1996 to 1998, over 2000 fish (including salmonids), were collected from 26 locations throughout the Columbia River basin. These samples were screened for over 131 toxic chemical chemicals including 26 pesticides, 18 metals, 7 PCB Aroclors, 13 PCB congeners, 7 dioxin congeners, 10 furan congeners, and 28 miscellaneous organic chemicals. Preliminary results indicate that the most frequently observed chemicals in fish tissue were 14 metals, DDT and its analogs, chlordane and its analogs, PCBs, dioxins, and furans. Most of the pollutants found in high concentrations are naturally occurring metals (mercury, copper, arsenic, and zinc) and legacy pollutants (dioxins, furans, PCBs, DDE, and chlordane). Legacy pollutants are of particular concern because they are persistent bioaccumulative chemicals.

Phase III of this study will be initiated in 2002. The relationship of water quality and fish health will be the focus of Phase III. Important objectives of this work include:

1. An examination of the anadromous fish health issues in the mainstem Columbia River resulting from toxic contaminant exposure,
2. Development of collaborative working relationships with state and Federal agencies to address these fish health concerns,
3. Identification of the additional data needs,
4. Heightened public awareness of the need to remove toxic contaminants from the mainstem Columbia River, and
5. Development of a long-term water quality monitoring plans the mainstem Columbia River for toxic contaminants.

II.G.4. Portland Harbor Superfund Cleanup Process

EPA added the Portland Harbor site to the Superfund National Priorities List in December 2000. The initial site area includes a six-mile stretch of the Willamette River extending from the southern tip of Sauvie Island to Swan Island in Portland, Oregon. As natural trustees for the site, CRITFC and its member Tribes are very interested in remediation proposals that impact the natural and associated cultural resource interests. These resources include anadromous fish (e.g., salmon, sturgeon, Pacific lamprey, and others) and the associated cultural resources.

A 1997 EPA sediment study of the area indicated that the sediments contain elevated levels of contaminants such as pesticides, DDT, PCBs, heavy metals, and PAHs. These chemicals pose a potential health risk to fish, wildlife, and humans. CRITFC and its member Tribes became involved with the site clean-up because it is included in the Tribes' treaty-reserved usual and accustom fishing area. Specifically, the Willamette River is a critical migration corridor for Pacific lamprey and for ESA-listed salmon and steelhead. Historically, Pacific lamprey has been found throughout the Willamette River reach. This river system may also provide important habitat for upper Columbia River basin Pacific lamprey displaced by the Columbia River dams.

II.H. Water Quality Models Used on the Columbia River Mainstem

Physically-based numerical models (or codes) can be useful tools to forecast the response of the a river system to management changes, provide insight into the relative importance of different physical processes, and to make estimates for historical conditions for which measured data are sparse. Models can represent the time variation of a system (unsteady), simulate a steady-state that does not vary in time, or assume a sequence of steady-state conditions (quasi-steady). Spatial variations in the system can be simulated in all directions (three-dimensional), account for plan-view variations by averaging over the channel depth (two-dimensional depth-averaged) , account for vertical variations by averaging across the channel width (width averaged), or simulate variations along the channel by averaging over the channel cross-section (one-dimensional). The hydraulic data requirements of these models are similar in that they require river bathymetry, main stem inflow, tributary inflow, and project operations. Water quality data typically includes meterology and inflow temperature for simulating water temperature, dissolved gas production as a function of spillway characteristics and discharge for dissolved gas simulations, and other data which will be specific to the water quality parameter being simulated. Computing times can vary depending on the size the area being simulated, spatial resolution, and temporal resolution. One-dimensional models tend to require the least amount of simulation time (0.5 to 2 hours, for example) while three-dimensional models of an entire reservoir may require 1-2 days of computing time.

Table 5. Partial List of Numerical Water Quality Models That Have Been Used Recently for Studies on the Mainstem of the Columbia and Snake Rivers.

Model Name	Type	Application	Reference
MASS1	One-dimensional Unsteady hydrodynamics and water quality	Total Dissolved Gas Temperature	PNNL (1999)
WQRRS	One-dimensional Unsteady hydrodynamics and water quality	Temperature Ecological Response	Normandeau Associates (1999)
RBM-10	One-dimensional Quasi-steady Hydrodynamics and unsteady water temperature	Temperature	USEPA (2001)
SYSTDG	One-dimensional Quasi-steady Total dissolved gas	Total Dissolved Gas	USACE (2000)
MASS2	Two-dimensional Depth-averaged Unsteady hydrodynamics and water quality	Total Dissolved Gas Temperature	PNNL (2000)
CE-QUAL-W2	Two-dimensional Width-averaged Unsteady hydrodynamics and water quality	Temperature	USACE (2000)
EFDC	Three-dimensional Unsteady hydrodynamics and water quality	Temperature	PNNL (2002)

III. Future Water Quality Program Needs

III.A. AA's Mainstem System Water Quality Plan Outline

In late fiscal year 2001, a group comprised of representatives of the AA, EPA, USFWS, and NMFS met to work on development of the Water Quality Work Plan as described in the 2000 NMFS biological opinion. These efforts are continuing at the present time. Progress to date has included the agreement on specifically identifying Actions to Avoid Jeopardy as described in Table 6, below. The group has also agreed on a set of principles to be pursued in the development and implementation of the Water Quality Plan. These principles include:

1. Providing a system-wide implementation plan for the 2000 FCRPS biological opinion as called for in Appendix B of the NMFS biological opinion.
2. The Water Quality Plan will form the framework for the state implementation plans prepared for the Columbia/Snake mainstem temperature and dissolved gas TMDLs.
3. The Water Quality Plan will form the framework (and justification) for the Corps to receive standard variances for TDG. If the Corps establishes long-term water quality planning, that would justify to the states the need to grant the interim waivers.
4. Full engagement and staff policy and technical commitment of all three Columbia River Power System Action Agencies: Corps, BPA, and BOR.
5. Commitment to an ongoing executive policy dialogue - Federal regional executives will meet on a regular basis to ensure an ongoing dialogue.
6. Sound Science - Participants commit to coordinate scientific efforts and use sound science to support decisions, actions, and implementation.
7. Commitment to Fund - This Water Quality Plan will require resources. RPAs will require resources from BPA and Congressional appropriations. The AAs will commit to allocate available resources to support the Water Quality Plan development and implementation. EPA will commit support to identify and support decisions on these resources.

To successfully complete and implement the Water Quality Plan for the FCRPS, a coalition of Federal, state, Tribal, and other appropriate entities is necessary to integrate the efforts of all interested stakeholders and to provide a connection with ongoing broad-scale coordination efforts in the basin. Water Quality Plan measures, such as ESA, CWA, and Fish and Wildlife Program measures, will be coordinated through application of the established processes. These include planning and review processes of the NWPPC, including the Independent Scientific Review Panel, CBFWA, and the NMFS Regional Forum. Some measures may also require congressional approval. NMFS, EPA, USFWS, and the AAs intend to support implementation of measures that successfully garner approval through these processes. A common approach for selecting the water quality, ESA, and fish and wildlife measures to implement will foster coordination among NMFS, EPA, and the AAs, and will increase effective use of limited available resources. The outcome of this coordinated approach will be a collection of measures the AAs undertake to serve the various statutory purposes within budgetary parameters. Recommendations approved via applicable processes will be identified in the water quality plan for implementation.

The 2000 NMFS biological opinion on the FCRPS calls for the development of a Water Quality Plan for the Columbia and Snake mainstem. The purpose of this Water Quality Plan is to move toward attainment of CWA standards consistent with the goals identified in the 2000 biological opinion. The Water Quality Plan will focus primarily on the physical and operational changes to both Federal and non-Federal dams to improve water quality. The 2000 biological opinion contains the following water quality goals:

> **TDG Goal** – The long-term TDG goal (10 to 15 years) is to reach the 110% TDG standard in all critical habitat in the Columbia and Snake river basins while taking actions to recover listed species in the basins. For anadromous fish, achieving the goal

would mean fish passage survival levels are consistent with the performance standards for the mainstem projects.

To assess the feasibility of reducing TDG to the 110% standard while still meeting the survival objectives of listed salmon and the performance standards of the biological opinion, EPA, NMFS, USFWS, and the AA commit to continued efforts to identify water quality improvement actions as set forth in the biological opinion. These efforts will lead to decisions on whether structural or operational changes exist that will allow FCRPS projects to achieve both fish passage and water quality objectives, or to encourage changes in non-Federal Columbia River basin projects that have a cumulative effect of reducing TDG levels systemwide. Information developed from these studies may also provide a basis for future decisions concerning beneficial use and water quality criteria revisions. Such decisions will result from a coordinated effort between EPA and NMFS and discussions with states, Tribes, and other interested parties. The EPA, NMFS, USFWS, and the AA will continue to work toward implementing a combination of actions that benefit both fish survival and water quality.

Part of the decision-making process to evaluate the structural and operational changes necessary to meet the 110% TDG standard will be based on a review of the existing data collected since the release of the 1995 NMFS biological opinion (see Section 6.2.6.1.1 of the 2000 NMFS biological opinion for a summary of the risk assessment for the spill program). GBT in juvenile salmonids is observed at all gas supersaturation levels, but the overall incidence and severity is low at FCRPS projects when managing fish passage spill to 115% to 120% TDG variance.

Water Temperature Goal – The long-term goal for water temperature is standard attainment in all critical habitat in the Columbia and Snake River basins. In the mainstem Columbia and Snake rivers, attainment of the temperature standard is very complex, due to a number of interrelated factors that affect water temperatures at certain times of the year and to the limited ability to alter water temperature in the mainstem. Therefore, in the near term, working with the state and/or Tribe with relevant regulatory authority, the interim goal is to move toward attaining the standard. Establishing TMDLs is expected to significantly promote progress toward the interim goal.

Table 6. 2002 Annual Implementation Plan -Water Quality Actions to Avoid Jeopardy

Strategy	**Substrategy**	**RPA Action Number**	**Project ID Number**	**Project Title**	**Lead Agency**	**2002 Work Expectation**	**FY2002 Work?**
Configuration	Water Quality	33	1704	Modify Water Supply to Dworshak NFH	COE	Install New Boiler System/Initiate Systerm 1 Mods	Yes
Configuration	Water Quality	134	1698	Bonneville Gas Fast Track	COE	Complete Construction.	Yes
Configuration	Water Quality	136	1714	John Day Gas Fast Track	COE	No Work in 2002.	No
Configuration	Water Quality	142	1800	McNary-Temperature Control	COE	Initiate CFD Model Development.	Yes
Configuration	Water Quality	134, 135	1660	Little Goose Gas Fast Track Deflectors	COE	Complete Plans and Specifications.	Yes
Configuration	Water Quality	135, 134	1661	McNary Gas Fast Track Deflectors	COE	Complete Construction of End Bay Deflectors. Complete Phase II Plans and Specifications.	Yes
Configuration	Water Quality	135, 134, 76	1659	Lower Monumental Gas Fast Track Deflectors	COE	Construct End Bay Deflectors. Complete Model.	Yes
Configuration	Water Quality	5, 132	1696	Water Quality Plan, 1-Year	COE/USBR/BPA	Included in 2002 Annual IP.	Yes
Configuration	Water Quality	82, 83, 71	1700	John Day Spill/Survival Studies	COE	Continue Evaluations.	Yes
Configuration	Project RM&E	114	1680	Fish Ladder Temperature Evaluation	COE	Collect Data. Prepare White Paper.	Yes
Configuration	Project RM&E	116, 34, 114, 115	1681	Adult Temperature Evaluation	COE	Continue Research.	Yes

Strategy	Substrategy	RPA Action Number	Project ID Number	Project Title	Lead Agency	2002 Work Expectation	FY2002 Work?
Operate and Maintain Fish Passage Facilities to Enhance Survival	Operation of FCRPS to Enhance Fish Survival	6, 131, 132, 133, 144	1687	Fish Passage Plan (FFP)	COE	Fish Passage Plan Issued	Yes
Configuration	Water Quality	136	1887	O&M – Chief Joseph Dam	COE	Spillway Modification	No
RM&E	Critical Uncertainties	141, 142, 143, 105, 199, 6, 144	1647	Juvenile Salmon Temperature Studies	COE	Initiate Research Studies.	Yes
Water Management	Flow Management	19	1844	Draft Dworshak to Cool Summer Water Temperatures at the Lower Granite Forebay.	COE/BPA	Releases Were Made for Dworshak to Attempt to Maintain Water Temperatures at the Lower Granite Forebay at or below 68°F.	Yes
Water Management	Other Actions	34	1855	Investigate Drafting Dworshak to 1500' Elevation	COE	Dworshak Draft to 1500' Study Proceeding.	Yes
Water Management	Other Actions	37	1707	Listed Fish in Columbia Basin Project Wasteways	USBR	Water Quality Monitoring Plan in Place. Monitoring Commences.	Yes
Water Management	Other Actions	39	1709	Return Flow Quality From Columbia Basin Project	USBR	Investigation Complete. Final Report in 2002.	Yes
Water Management	Other Actions	131	needed	Monitor TDG Effects	COE/USBR	Monitor and Report TDG in FCRPS System..	Yes
Water Management	Other Actions	132	needed	Review of TDG Monitoring Stations	COE	Issue Representativeness Report.	Yes

Strategy	Substrategy	RPA Action Number	Project ID Number	Project Title	Lead Agency	2002 Work Expectation	FY2002 Work?
Water Management	Other Actions	132	same	Review of TDG Monitoring Stations	COE	No Funding for FY2002.	No
Water Management	Other Actions	132	same	Review of TDG Monitoring Stations	COE	Evaluate Identified Problem Stations.	Yes
Water Management	Other Actions	133	needed	Develop TDG Model	COE	Update TDG Production Relationships.	Yes
Water Management	Other Actions	133	needed	Develop TDG Model	COE	Update the SYSTDG Users' Manual and Documentation.	Yes
Water Management	Other Actions	133	needed	Develop TDG Model	COE	Technical Review of the Model.	Yes
Water Management	Other Actions	133	needed	Develop TDG Model	COE	Statistical Summary of Historic Gas Data.	Yes
Resident Fish	Bull Trout Operations	139	1716	COE to Investigate TDG Abatement at Dworshak Dam	COE	Initiate Hydrologic and Field Analysis.	Yes
Operate and Maintain Fish Passage Facilities to Enhance Fish Survival	Operations RM&E	FSW7.A.1	1885	O&M – Albeni Falls Dam	COE	Spill Test – TDG Report	No
Water Management	Reservoir Operations	FWS8.3.h	260	Monitor Water Temperature in Lake Koocanusa During May and June	COE/BPA	Monitoring Will Be Conducted in 2002.	Yes
Water Management	Other Actions	FWS8.2.a.1, 137	241	Test Libby Spillway for TDG in 2002. Evaluate Gas Throughout the Kootenai River.	COE	Conduct Spill Test in 2002.	Yes

Strategy	Substrategy	RPA Action Number	Project ID Number	Project Title	Lead Agency	2002 Work Expectation	FY2002 Work?
Resident Fish	Bull Trout Use	FWS10.A.3(1)	1794	Bull Trout Use of Lower Snake River Reservoirs.	COE	Evaluate Temperature and Gas Effects.	Yes
Operate and Maintain Fish Passage Facilities	Operations RM&E	FWS8.2.a.5	needed	O&M – Libby Dam	COE	Gas Abatement Feasability Study	Yes

Appendix B of the 2000 NMFS biological opinion also identifies actions for the FCRPS that further CWA objectives, but are not called for in the ESA RPA. These actions are listed in Table 7, and are studies to investigate additional measures to reduce TDG and water temperature that may be considered for implementation in the future. The studies in Table 7 are appropriate as ESA conservation measures that will require further ESA consultation when they are further developed, analyzed, and proposed for implementation.

For example, early discussions of the gas abatement alternatives presented in Table 7 have identified some initial concerns for feasibility and biological impacts. The BOR has conducted extensive feasibility studies of the gas abatement alternatives at Grand Coulee and have reported the findings to the region. Excessive implementation cost projections have resulted in pursuit of other alternatives, namely the Grand Coulee/Chief Joseph composite operational/structural modification. Other alternatives that have been considered for the lower Snake and lower Columbia river projects, e.g., side channel spillway, raised stilling basin or baffled spillways, have proven problematic for various reasons. These reasons include safe fish passage through the full range of anticipated flows up to 7Q10, which would require extensive engineering and construction to properly accommodate required energy dissipation below the spillways.

Table 7. List of CWA Actions in Appendix B that are not called for in the 2000 FCRPS Biological Opinion RPA

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

III.B. U.S. Army Corps of Engineers

III.B.1. DGAS/Fast-Track - Lower Granite Dam

Deflectors exist on all eight-spillway bays at Lower Granite. These deflectors are 12.5 feet long and have radiused transitions. Possible future modifications might include the addition of pier nose extensions and relocating the deflectors at an elevation optimized for current operation. Regional consideration of these modifications will be initiated in the future. A near field test of the existing spillway is needed to assess current structural TDG performance. Near field TDG testing has been delayed to avoid interference with ongoing research on RSW and surface collection prototypes at Lower Granite.

III.B.2. Seattle District Corps – Chief Joseph Spillway Deflectors Construction

Chief Joseph flow deflectors were not funded by Congress for final design in FY02. Both Congress and the President expressed a preference for "no new construction starts." Future funding remains uncertain. If the project is not identified in the President's or Congress' budget in FY2003 it would require a "Congressional Add" for funding.

III.B.3. Seattle District Corps – Libby Dam Gas Abatement

The USFWS 2000 Biological Opinion called for tests to determine the effects of spilling water at Libby Dam are scheduled for 2002. If testing during spring 2002 establishes that 5,000 cfs can not be passed over the spillways at Libby Dam while complying with the state of Montana's 110% TDG criterion, spillway deflectors or an additional turbine are recommended to be operational by spring 2004. The USFWS has also recommended a second 5,000 cfs increment of increased release capacity at Libby Dam by 2007, and again a consideration in this recommendation is to preclude violation of Montana's 110% TDG criterion. Water passing through the turbines at Libby Dam is generally well below this state CWA criterion.

III.B.4. FY2003 and Beyond Corps Water Quality Plans

In January 2002, the Corps is planning to review its Operational and Maintenance program for 2003-2006 to evaluate the potential for budget reprogramming for future years. The reprogramming evaluation will help to determine water quality actions already existing in the baseline program, and will help to determine those actions necessary to meet the water quality items of the 2000 biological opinions to avoid jeopardy and those actions above and beyond the biological opinions in support of state and Federal TMDL development.

III.C. BPA FY 2003 and Beyond Water Quality Project Implementation Planning

The annual BPA project selection, implementation and funding process relies on the NWPPC process. The coordinated regional review process addresses the overlap between the NWPPC's program and BPA's ESA responsibilities under the NMFS and USFWS biological opinions of December 2000. In the BPA process, priority is given to proposals that:

1. are consistent with the NWPPC's Fish and Wildlife Program,

2. are consistent with NMFS' or USFWS' 2000 biological opinions or the AA Implementation Plan,
3. are consistent with Federal trust and treaty responsibilities,
4. are of scientific merit (rely largely on ISRP review),
5. are implementable (technical feasibility), and
6. include the appropriate level of effort and costs

These are general criteria, and should not be taken as the only selection criteria to be used in project selection and ranking. They should be viewed as a filter. Future project solicitations and the project selection criteria, may contain additional, specific requirements adapted for that mainstem/systemwide Province and the needs of the Water Quality Program.

III. D. Future Water Quality Needs in the Mainstem Columbia River Basin

The quality of surface waters is clearly an item of great importance to the Columbia River basin. Regional planning and implementation activities are increasing to properly reflect this importance. Development and negotiation of the 2000 NMFS FCRPS Biological Opinion was a collaborative effort between the fisheries agency and the EPA as well as the AAs and the other regional entities. The NMFS biological opinion addressed specific water quality needs in a suite of action items as part of the RPA. Similarly, the 2000 USFWS Biological Opinion also included several water quality topics regarding bull trout and sturgeon, in particular. The NWPPC is also recognizing the importance of water quality by calling for the development of a water quality component of the Mainstem and Systemwide Program Summary as a basis for future planning in the Provincial Review Process. Implementation of these various programs is anticipated to bring about an unprecedented improvement in mainstem water quality.

Simultaneously the states, Tribes and the EPA are developing TMDLs for a variety of water quality parameters, especially TDG and temperature in the mainstem Columbia and Snake rivers. Other TMDLs are also being pursued for the tributaries and on chemical water constituents that could affect mainstem water quality as the tributaries contribute flows to the mainstem.

The legal, institutional, technical, and scientific complexities of water quality are now being addressed in a systemwide Water Quality Plan. This effort has senior representatives from the NMFS, EPA, BOR, BPA, and USFWS collaborating on a multifaceted plan to bring reality to the water temperature and dissolved gas goals discussed above. Tables 6 and 7 above list a series of programs, projects, and operational activities aimed at the Federal hydrosystem and provides the nucleus for the development of the Water Quality Plan. All of these activities speak to the recognized importance of water quality as a future long-term effort in the basin.

On a more technical front, the region has moved forward on a number of topics. In the near-term the focus of most water quality projects being implemented will be water temperature and dissolved gas. Efforts initiated by the EPA have resulted in scientific guidance on the setting of temperature criteria for regional waters. Measures in the NMFS biological opinion are planned to provide additional water temperature monitoring strategies and improved models for river management.

The region has learned a great deal about the biological effects of TDG. Other accomplishments in the region include the Corps' DGAS program. Now nearly complete the program has identified various gas abatement alternatives and provided guidance on the dissolved gas benefits, potential biological effects, costs and gas abatement effectiveness. The Corps and the region were quick to recognize that spillway deflectors based on recent technological advances were quite effective in lowering TDG due to spill.

Although the above discussion highlights some of the major water quality (Section II) accomplishments made by the regional entities, some important topics and concepts remain. The biological opinions and fish and wildlife programs have managed to highlight the importance of water quality and to adopt and implement significant new concepts and projects. However, this report would be incomplete if it did not consider some of the thoughts and suggestions from water quality experts on matters not yet engaged. The following is a short collection of topics of concern.

III.D.1. Columbia River Basin Gas Bubble Trauma TDG Threshold

In the years preceding the NMFS biological opinions it became imperative to improve the passage and survival of downstream migrating juvenile salmon. For several reasons spilling water over the project spillways was recognized as a benign strategy to accomplish passage improvement. In spite of the high energy environment of the spillways juvenile mortality is in the range of 0% to 2% (Whitney et al. 1997). Spill has been demonstrated to be highly efficient, often passing more fish per given volume of water than would be expected. Furthermore, spill is an immediately applicable strategy compared to the longer timeframes required to implement major capital fish passage improvements at the mainstem dams. However, the downside to spill is the increased TDG in the river waters.

At the time of the first NMFS FCRPS biological opinion, the Federal, state, and Tribal fishery agencies considered the application of spill strategy to improve fish passage; the state water quality agencies of Washington, Oregon, and Idaho asked the fisheries entities to evaluate the relative risks to fish from spill generated supersaturated dissolved gas as compared to turbine passage. A risk assessment was conducted that weighed the benefits of spilling water to improve passage of listed stocks against the risk associated with increased levels of TDG (WDFW et al. 1995). At that time the water quality standard required TDG be controlled to 110% or less dissolved gas. To implement a spill program temporary waivers of water quality standards were required.

The fishery agencies' risk assessment concluded that a program of managed voluntary spill during the juvenile migration period (April-August) at mainstem projects was essential to protecting the beneficial uses of the Snake and Columbia rivers, including salmon. Based on extensive review of the scientific literature and dissolved gas experience of the regional fish experts, the report advised that the water quality criteria for TDG concentrations associated with the designated uses of surface waters should be modified to allow gas concentrations in the range of 120-125% based on a 12-hour average. The risk assessment investigated whether or not there is a threshold gas concentration where survival benefits from spill would be counterbalanced by increased mortality from GBT. The risk assessment found that migrants exposed to TDG in the range of 120-125% over a time period approximating downstream passage through the FCRPS to the ocean would still benefit from the use of spill to avoid turbine mortalities despite the potential adverse effects of GBT. The analysis also suggested these gas levels would be safe for adult migrants.

The biological monitoring program over the last six years has collected thousands of specimens and evaluated them for GBT signs. Very few signs are seen when the TDG is below 120% (NMFS 2000c). Gas bubble trauma signs do not begin to increase until gas exceeds 125%. Severe signs of GBT are not seen until TDG is approaching 130%. Similar results are noted with adult salmon and resident fish species. Yet the dissolved gas standard is 110%. It is difficult to reconcile strict adherence to the standard when compared to the value of increased passage and survival of listed fish stocks as a result of the voluntary spill program.

The discrepancy between the gas standard and the monitoring program results is likely explained by "depth compensation." The Columbia and Snake river reaches affected by the FCRPS are a series of reservoir pools. The majority of these waters provide ample depth for migrating juvenile and adult salmonids, as well as resident species, to occupy waters below the compensation depth, that is, a depth that provides sufficient hydrostatic pressure to compensate for the elevated dissolved gas levels.

Depth compensation is a function of the fact that gas solubility increases with increasing pressure. For each meter of depth there is a 10% reduction in the TDG saturation level relative the surface saturation (Weitkamp and Katz 1980). This means that for protection from 120% TDG near the surface, fish only need to travel at a depth of 2 meters or more. More recent studies have found that juveniles migrate at compensatory depths (Maule et al. 1997b; Beeman et al. 1998, 1999; and Gray and Haynes 1977). These depths are sufficient to negate predicted mortalities from the mid-1970s laboratory investigations that were conducted in shallow laboratory troughs, raceways, and tanks. That may also explain why the annual biological onitoring program detects fewer GBT signs than might have been expected based on the 1970s tests.

The results of the GBT monitoring program have led to recent discussion regarding the appropriateness of the 110% TDG standard to the Columbia and Snake rivers, especially in light of the extensive and costly efforts being pursued on other fronts to recover the runs of listed stocks. The recent draft of the states' Total Maximum Daily Load for Lower Columbia River Total Dissolved Gas reports that consideration has been given to modifying the Federal water quality standard or establishing a site-specific criterion for TDG in the Columbia River. The states' draft supports the evaluation of the appropriateness of the water quality standard for specific sites on the Columbia in terms of TDG impacts to aquatic species. Further, the states' draft advises that any revision to the standard would need to proceed through a scientific review to protect all aspects of the standard's beneficial use designation. The question now becomes one of defining the requirements of that scientific review.

Recommendations

Identification of remaining critical uncertainties regarding TDG, biological effects, GBT, monitoring, spill and passage. This effort would identify specific questions, critical uncertainties, and research needs. There may not be sufficient information to answer all the needs. Topics may include additional information about:

1. Depth compensation and fish migratory behavior;

2. Effects of TDG on resident fish species, particularly sturgeon, bull trout, and lamprey, as well as benthic invertebrates;
3. Effects of TDG on adult salmon migrants. .

Efforts to gather the data and information required to support an altered water quality standard should be pursued as expeditiously as possible.

III.D.2. Comprehensive Water Quality Knowledge in the Columbia River Basin

Knowledge of the basic quality of surface waters in the Columbia River basin is essential to the pursuit of listed stocks recovery. However, our current knowledge regarding the region's water quality may not be as comprehensive as we would like to think it is. Some recent studies by the U.S. Geological Survey National Water Quality Assessment have found surprising levels of pesticides in some areas of the region that people might have assumed were fairly high quality waters.

A great deal of effort and funds has been expended to reconfigure and operate the FCRPS in a manner that is protective of migrating fish. Operational and structural modifications are conceived, studied, debated, installed, and operated to insure safe salmonid passage upstream and downstream. Subbasin planning and watershed enhancement have been pursued in the Columbia River basin by the NWPPC's Fish and Wildlife Program since the early 1980s. Decades of research have gone into investigating the impacts and corrective actions that provide relief from elevated TDG supersaturation and elevated water temperatures. Yet one of the most basic water quality factors is unknown, and its potential impacts to fish are not fully understood. Pollutant chemicals from industry, agriculture, residential development, mining, forestry practices, and municipalities can enter the water through a variety of routes and their basic impact on water quality and on salmonid enhancement efforts remains poorly understood. This is not to say that concentrations of the pollutants are present in lethal amounts, but they can be present in apparently minor, yet biologically active, concentrations, and resource managers remain unaware of this fact.

There are several sources of needed water quality information. In the Columbia River basin, water quality information sources include the EPA and state water quality agencies. These entities monitor surface waters for guideline and standards compliance. Some of the data most pertinent to this topic may be found in the CWA Section 303(d) lists of water quality impaired streams. Another source of water quality data is the hydroelectric owners and operators, such as the Corps, the PUDs, and private dam operators. These entities routinely record water temperatures, dissolved gas, and other measurements associated with their operations.

In spite of these efforts and the amount of water quality information that is available for some watersheds, there are important components of the water quality information that remain unaddressed. Even with the listing of some streams as water quality limited, i.e., 303(d) listed, the data on water quality constituents identified as supporting these findings are frequently limited and may not include information on the most critical toxicants. The constituents routinely seen in 303(d) lists include water temperature, dissolved oxygen, sediment flow, bacteria, pH, aquatic weeds and biota, habitat modification, and toxins. This last constituent, toxins, is not a frequent cause of listing, yet recent efforts have revealed that toxic pesticides are far more prevalent than once thought and occur in problematic concentrations.

In 1986, a concerted effort to assess water quality was started by the U.S. Geological Survey (USGS). The National Water Quality Assessment (NAWQA) program was initiated and builds upon existing bases of water quality information from multiple Federal and state agency efforts. The USGS program has collected spatial and temporal data on low-level contaminants of currently and historically used pesticides from over 40 large river systems throughout the nation. In the Columbia River basin, the USGS efforts in the 1990s have characterized the waters of the upper Snake River drainage, the Willamette and Yakima River basins, the central Columbia Plateau, and some areas of the Puget Sound basin.

With regard to toxic constituents, some results of the NAWQA efforts in the Pacific Northwest have been alarming and serve as a major motivation in the conclusion urging the consideration of an expanded water quality knowledge and watershed health as a fundamental criterion in the Provincial Review Process project selection processes. The analytical detection capabilities of the NAWQA program are significant with a minimum detection level approaching one part per trillion (0.001µg/L). In waters, fish tissues, and stream bottom sediments, one or more of over 190 pesticide compounds are routinely detected. Reviewing the reports from the NAWQA Program in the Pacific Northwest commonly reveals findings such as the following:

1. Pesticides detections are widespread in stream and ground waters in urban and agricultural areas. Concentrations fluctuate with the seasons.
2. The frequency of pesticides is greater than the USGS investigators had expected. At least one pesticide was found in almost every water and fish tissue sample collected. Moreover, individual pesticides seldom were found alone. Almost all samples had multiple pesticides detected.
3. NAWQA results indicated a high potential for problems in any agricultural and urban stream where concentrations often approached or exceeded established water quality guidelines.
4. Water quality standards and guidelines are available for many pesticides as individual constituents. However, this does not account for the complex mixtures of pesticides or the breakdown products that are often observed in watersheds.
5. Standards and guidelines are based on laboratory tests that have a limited application to the long-term exposures to low levels of pesticide mixtures or seasonal pulses of higher concentrations more typical of the watersheds monitored. The actual effects of these exposure patterns on aquatic organisms are not well understood.
6. Hormone levels in fish show signs of possible endocrine system dysfunction when pesticide exposures have been high. The sub-lethal effects of most pesticides in common use are poorly understood or completely unknown
7. Insecticide concentrations exceed aquatic-life guidelines in about half of the streams tested on the national level. Several irrigated areas in the Western states had among the highest insecticides levels observed.
8. Resident fish species from the Yakima River basin revealed some of the nation's highest tissue concentrations of DDT+DDE+DDD. Although DDT concentration in the Yakima system of agriculturally-influenced watersheds has decreased, the concentrations still exceed the EPA chronic-toxicity aquatic life exposure criterion.

9. Salmonid homing and predator-avoidance behaviors are being affected by the low level concentrations of pesticides being routinely detected in the NAWQA Program. It is also suspected that spawning behaviors are affected at these concentrations as well.

Impaired water quality in a subbasin could be a significant impediment to the success of expensive mainstem fish passage enhancement activities. This result is avoidable by careful investigation of water quality at the outset. Areas affected by agriculture, irrigation, forest practices, grazing, mining, or industrial and urban activities warrant careful attention. The water quality information necessary is likely to be available and the questions can be answered quickly. In some cases, further water quality monitoring may be necessary, but the benefit to a fish passage project could be significant and justify a minor delay and associated costs.

Recommendations

1. At the outset of mainstem projects, one of the first critical tasks should be a review of water quality to determine if problems have been detected in the reach. This review can include consideration of CWA 303(d) listings and collection of results from concerted water quality monitoring efforts such as NAWQA.
2. If it is determined that water quality information is incomplete or unavailable for the mainstem reach in question, a short-term screening assessment is recommended. Water quality experts could provide guidance identifying potential contaminant sources, recommending a focused scope of baseline water quality screening and identifying possible problematic constituents.
3. Review the anthropogenic activities in the province to aid in identifying contaminant constituents potentially contributing to the degraded water quality. These include municipal, irrigation, forest practices, mining, grazing, and industrial and agricultural activities. All have characteristic effects on water quality.
4. Review the lists of recorded province and mainstem water quality constituents for chemicals that bio-accumulate. Chemicals demonstrating this characteristic can have significant ecological effects as well as impacts to human health.
5. If water quality issues are identified in the mainstem province, consider the impacts of these issues to proposed fish habitat restoration and fish passage activities and to the fish populations and other aquatic life. Consider long-term monitoring for continued contaminants and the efficacy of water treatment remedial activities.

III.D.3. Scientific Uncertainties Associated with Water and Sediment Quality Evaluations

The Pacific Northwest has been considered an area of pristine, high quality waters. However, recent programs evaluating the quality of Pacific Northwest rivers, lakes, and estuaries have revealed surprising outcomes. Programs such as the USGS's NAWQA have revealed the presence of pesticides in waters, sediments, and fish tissues that might have heretofore been thought relatively free of contaminants. This was the case in NAWQA sampling done in the Willmette, Yakima, upper Snake, central Columbia, and Puget Sound environs. Recognition of these facts, coupled with concerns for recent ESA listings of salmonids, has prompted the Ecotoxicological and Environmental Fish Health Program (Ecotox Program) of NMFS to develop ecotoxicological summaries of the fourteen major classes of chemical contaminants that are known or suspected to pollute rivers, lakes, and estuaries of the Pacific Northwest. The primary goal of this effort is to provide scientific information and guidance to the Technical Recovery Teams and others in the Region regarding the importance of water and sediment quality as potentially limiting factors for the recovery of threatened or endangered (T/E) species. The Ecotox Program will screen the toxicological literature for studies that yield high quality data and focus on endpoints that have the most relevance for anadromous fish.

The fourteen contaminant classes below are of interest due to the potential for effects of significance for the growth, survival, migration, behavior, physiology, immunology, and reproduction of listed stocks of salmon. The contaminant classes are:

Chlorinated solvents	Metals	Organobromines
Current Use Pesticides	Pharmaceuticals	Organotins
Cyanide	Plasticizers	Surfactants
DDT	Polychlorinated Biphenyls	Trifluoracetic acid
Dioxin	Polycyclic Aromatic Hydrocarbons	

As the effort of the Ecotox Program moves forward it is anticipated that there will be areas of scientific uncertainties. To this end, a secondary goal of the effort will be to identify these areas, particularly as they pertain to habitat quality and the environmental health of fish. An effort should be initiated to respond to the uncertainties identified and to initiate the required investigations to provide the required knowledge base. A discussion of some of the more pertinent uncertainties follows.

1. Life stage toxicological data is limited. Due to the migratory nature of these stocks, the eggs, parr, smolts, and adults occupy different freshwater and estuarine environments for varying exposure periods at different points in the life cycle. Each of these environments may present different contaminants and mixtures of pollutants that could yield a variety of lethal and sublethal results. This is an area of very limited past investigation. Therefore, ability to interpret or predict effects is likely to be impeded or totally lacking.
2. There is a lack of information on the effects of chemical mixtures on salmonids. Although the relative acute or chronic toxicity of single pollutants may be available, the impacts of mixtures, sequential lifetime exposures, and bioaccumulation, working in concert with other stresses imposed on juvenile and adult migrants, is largely unknown.
3. For some contaminants, there is very little toxicological data available for fish or aquatic systems. For example, a complex array of pharmaceutical drugs is currently discharged from wastewater treatment plants into salmon habitat. These include synthetic hormones, blood pressure medications, antidepressants, cholesterol medications, etc. The effects of these chemicals on aquatic ecosystems are almost completely unknown. In this and similar cases, there may not be enough scientific information for the Ecotox Program to adequately evaluate the potential effects of these contaminants on salmonids or their food supply.
4. For those contaminants for which toxicological data are available, the data may not be of sufficiently high quality. High quality data only originate in properly controlled

laboratory studies with sufficient number of quantitative measurements to allow rigorous statistical analysis.

5. The data that are available may not be highly relevant to the essential biological requirements of Pacific salmon or the Columbia River basin in which the fish spawn, incubate, hatch, rear, and migrate. In this context, studies that specifically address the toxicological effects of environmental contaminants on T/E salmonids are highly relevant. Also, the studies with the most relevance are those that evaluate the effect of chemicals at exposure concentrations or durations that might be expected under conditions found in the Columbia River and adjacent waters.

The Ecotox Program will identify the best possible science for the different contaminant classes; that is, those studies that address exposures at sensitive life history stages, exposure to contaminant mixtures, and are both highly relevant and a source of high quality data. However, it is anticipated that even the best available science will often consist of toxicological studies that do not adequately address relevant parameters, and may be of intermediate or low relevance or data quality. Findings of this nature will provide little guidance as to the potential impacts of problem contaminants. Consequently, for some contaminants, there may be a considerable amount of scientific uncertainty associated with the available toxicological data.

Recommendations

A renewed emphasis on reliance on natural production and activities enhancing natural production of salmonids as an avenue to recovery of salmonids T/E listed stocks has occurred in the Columbia River basin. The most scientifically sound information for the fourteen classes of contaminants identified above is now being scrutinized and assembled by the Ecotox Program. The information will provide a working database pertinent to the regional recovery efforts. Essential information, data gaps, or difficult toxicology questions will arise that can only be answered by initiating focused, quick response, and rigorous research. The urgency of the salmon recovery efforts makes it imperative that as questions arise for which there are no answers at hand, efforts to gain those answer must begin promptly. Preparations to facilitate these quick actions and initiate necessary studies should be made in the near term. These preparations would include:

1. Identification of the agencies and laboratories with the expertise and facilities to conduct required investigation.
2. Identification (to the extent possible) of critical uncertainties already apparent from the work of the Ecotox Program and other toxicologists of the region.
3. Preparation of the appropriate pre-contractual arrangements supportive of shortening the response time.

III.D.4. CRITFC View of Salmon Recovery and Toxic Contaminants

Because salmon are at the heart of Tribal culture, the potential impact of toxic contaminants on salmon health and recovery is of great importance to the Tribal community and economy. The CRITFC member Tribes will therefore be directly involved with the development and implementation of water quality programs that address toxic contaminants in addition to other water quality issues. This participation builds upon CRITFC’s participation in ongoing regional water quality processes described earlier in the document (See Section II.G). Continued, direct involvement will further advance the goal of water quality restoration in the Columbia River basin (See Previous Discussion on Pesticides, Sections III.D.2 and 3).

Loss of critical salmonid habitat due to degraded water quality has generally focused on water quality parameters such as dissolved oxygen, temperature, total dissolve gas, sedimentation and flow. Less attention has been placed on habitat loss resulting from the presence of toxic contaminants. This apparent oversight is significant because of the acute and chronic impacts these contaminants can have on anadromous fish.

Toxic contaminants have been detected in fish tissue collected from the mainstem Columbia River and its tributaries (EPA in press). In addition, USGS studies have shown the presence of contaminants in Pacific Northwest waters and biota (USGS 2000 a,b and 1998), yet little is know about the role this exposure plays in salmon decline and subsequent recovery efforts.

The presence of toxic contaminants in the Columbia River basin is a concern to the CRITFC member Tribes because salmon and Pacific lamprey reproduce in fresh water where toxic contaminants are more prevalent. Sturgeon has also been affected (see Discussion on White Sturgeon and Contaminants). Furthermore, the eggs and early life stages are the most susceptible to impacts from contaminant exposure (Hoffman 1994; Adams 1994). These impacts can be direct (e.g., endocrine disruption, changes to immune function, behavioral changes, impaired growth or development) or indirect (e.g., altered habitat, altered food supply) (Ewing 1999).

Food-borne exposure is an important source of the pollutant body burden in salmon and Pacific lamprey. For example, the Pacific lamprey ammocoete may stay buried in soft substrates for up to seven years. At this larval stage, the Pacific lamprey uses a filter-feeding mechanism. This type of feeding creates the greatest exposure to water- and sediment-borne contaminants from ingestion of contaminated sediment, waterborne organic material and detritus, and dissolved substances within the water column. The parasitic feeding of the adult Pacific lamprey creates a secondary exposure pathway via the body fluids of the host organism. Other potential routes of exposure include ingestion of salmon eggs and ammocoete dermal exposure.

Sources of pollutant body burden in salmon include ingestion of contaminated prey, transport into the blood via the gills, and incidental ingestion of sediment or dissolved substances within the water column. In addition, preliminary research conducted at the Hatfield Marine Science Center indicates that juvenile fall chinook can take up chemical contaminants during the relatively short time spent in the lower Columbia River.

Because of the potential health risk to Pacific lamprey and endangered salmon, water quality management programs in the mainstem Columbia River must incorporate the reduction of toxic contaminants in the salmon recovery effort. These programs should address five main areas:

1. Research,
2. Contaminant Sources,
3. Long-term Monitoring,
4. Institutional Framework, and
5. Partnerships.

Recommendations

1. Research: The goal of toxic contaminant research in the mainstem Columbia River is to describe the link between salmon recovery and toxic contaminant exposure. This research should include but not be limited to studies that: 1) evaluate whether water quality standards for biocummulative contaminants protect salmon and other aquatic organisms; 2) describe the impact of dams on the physical/chemical processes that influence contaminant mobility and availability to aquatic organisms; 3) identify the exposure pathways for salmon, white sturgeon, and Pacific lamprey; 4) identify habitat in the mainstem Columbia River used by salmon, Pacific lamprey, and white sturgeon associated with high toxic contaminant concentrations (e.g., buried transformers); 5) assess salmon and Pacific lamprey recovery from remediated sites; 6) define the extent to which contaminants impact salmon, Pacific lamprey, and white sturgeon health in the mainstem Columbia River; 7) identify data gaps; and 8) determine whether Pacific lamprey are being forced into areas with high contamination due to mainstem obstructions.
2. Contaminant Sources: Pursuant to the salmon restoration goals identified in *Wy-Kan-Ush-Mi Wa-Kish-Wit*, water quality improvement programs should focus on the elimination of toxic source contamination and the reduction of other pollutants. Potential sources of toxic contaminants include agriculture, legacy pollutants, industrial discharges, urban runoff, combined sewer overflows, upstream sources, and air emissions. An important component of this effort will include outreach to the Tribal and non-Tribal community on the potential harm caused by toxic contaminants and how to reduce or eliminate the use of these chemicals. Another critical element to this effort is the development of a database for tracking the use, type, and discharge of toxic chemicals in the mainstem Columbia River.
3. Long-term Monitoring: Long-term instream monitoring of critical salmonid habitat is essential to determining the extent and nature of toxic contaminant exposure experienced by salmonids and lamprey in the mainstem Columbia River. These monitoring programs should be tailored to address critical chemicals of concern and data gaps. As a tool in source reduction, these programs should also address the issue of contaminant contributions from naturally occurring vs. human sources or activities (See Discussion on Pesticides and on Sediment Contamination).
4. Institutional Framework: An important first step to source reduction is to ensure that all pertinent regulatory authorities (e.g., Clean Water Act, Clean Air Act, and state law) are fully funded and implemented. The existing statutes should also be evaluated for their ability to protect salmonids and other aquatic organisms from toxic contaminant exposure.
5. Partnerships: Toxic contaminants in the Columbia River basin and mainstem Columbia River are widespread with biological, regulatory, economic, policy, human, and fish health implications. Establishing partnerships with the impacted communities will facilitate our efforts to eliminate this hazard to fish and subsequently, humans. Much of this work will be more effective if conducted through partnerships with the regulatory agencies, the Tribes, public interest groups, and the research community. Potential partnerships may include, but are not limited to:
   - Washington Department of Ecology,

- Oregon Department of Environmental Quality,
- Oregon Department of Agriculture,
- Municipal Governments,
- National Oceanic and Atmospheric Administration,
- National Marine Fisheries Services ,
- U.S. Geological Survey,
- U.S. Bureau of Reclamation,
- U.S. Fish and Wildlife Service,
- University Research Programs,
- EPA, and
- Local Watershed Councils.

USGS and CRITFC: Use a Geographic Information System to increase access to and analyses of water quality information for the

Mainstem Columbia River and Selected Tributaries

Organizations are producing more and more information pertaining to habitats, water quality, and pollutants in the Columbia River Basin. However, considering the large scale of the system and the complexity of the interactions that influence the fishery, it is sometimes difficult to effectively combine the results from smaller studies with the larger picture to develop basin wide management strategies.

Recommendation: By developing a geographic information system (GIS) to investigate geographic relationships in water quality data for the Mainstem Columbia River and some of the tributaries, results from a number of more localized studies can be linked together for enhanced analyses. This linkage will allow resource management organizations to interpret and present complex interactions of factors that influence the health and production of the Columbia River fishery.

Effective use of GIS would provide the opportunity to view the continuity of terrestrial and aquatic habitats along with a dramatically improved capacity to examine issues such as the effects of contaminants on human and fish health at a basin wide scale. Land use practices, point source inputs of contaminants, movements and availability of contaminants to fish relative to their location could be examined. Identification of areas where potential heavy contamination of fishes might be present would be more easily identified; thus enabling managers to more effectively allocate resources. By examination of the spatial component of contaminants in fish on a large scale, potential sources of these contaminants could be identified and remedies developed.

By incorporating data on the physical, chemical, and biological characteristics of the habitats of fishes in a GIS, limitations on production of various fishes should be more easily determined. Updating the information in the GIS as new studies are completed would allow analyses that could lead to improvements in management strategies leading to rehabilitation

III.D.5. Lake Roosevelt Water Quality Dynamics

The Columbia River waters of Lake Roosevelt above Grand Coulee Dam serve the region as a major source of power generation, flood control and irrigation waters. These waters include multiple tributary systems including the Kootenai, Pend Oreille, Kettle and Spokane rivers, which are all transboundary and/or interstate systems. The Columbia River itself originates in British Columbia.

Point source and non-point pollutant sources both in the U.S. and Canada negatively impact the water quality in this complex system. Industrial mining operations and paper and pulp mills just across the international boundary in Canada have been identified as sources for metals, PCBs, dioxins and furan contaminants in Lake Roosevelt. These contaminants have been found in sediments and in Lake Roosevelt fish.

Hydropower operations in both the US and Canada affect other water quality parameters such as temperature and TDG. In the spring and summer months elevated TDG can be a problem due to spill at the Hugh Keenleyside project on the Columbia, spill at Libby or the five Canadian projects on the Kootenai River, and spill at Albeni Falls, Box Canyon, Boundary, Seven Mile and Waneta dams on the Pend Oreille River.

These negative water quality impacts, whether they originate in Canada or the U.S., can migrate back and forth across the international boundary via these transboundary waters, violating international, Federal, state and Tribal water quality laws, including unquantified damages to the resources and all aquatic species in the system. Once the water quality of the rivers flowing into Lake Roosevelt is degraded, the final distribution, fate and effect of these degraded waters in the Lake and in the remainder of the Columbia River basin below Grand Coulee Dam become an issue. The dynamics of contaminants in Lake Roosevelt, and more recently, TDG, have been a concern of several management entities, yet the issue remains unresolved.

The Transboundary Gas Group (TGG) was formed in the spring of 1998. This is an international group of scientists concerned about spill-generated TDG, gas bubble disease in fish and TDG in the upper Columbia River watershed. Lake Roosevelt was identified as a critical area of concern, referred to as the "missing link" in the TDG story, as little has been done to characterize TDG in this system. The overall long-term goal of the TGG is to "reduce system-wide TDG to levels safe for all aquatic life in the most cost-effective manner possible..." The membership of the group recognized that to adequately pursue this goal it is imperative to understand the dynamics of TDG once it enters the water of Lake Roosevelt. This same concern could be stated for any other pollutant entering this system through tributary waters.

Lake Roosevelt is currently listed as an impaired water body under the Federal 303(d) list for arsenic, dissolved oxygen, mercury, temperature, sediment toxicity and TDG (see Table 1). EPA and the state of Washington are currently formulating a strategy to deal with TDG in the upper portion of the system, but a conceptual framework of how this will be accomplished is not clear. It is likely that the Grand Coulee Dam and other downstream projects will be a focus of TDG and temperature improvements, but these goals may not improve water quality in Lake Roosevelt.

EPA is currently conducting an expanded Site Investigation to characterize the tributary and lakebed contaminants in the U.S. portion of the upper Columbia region including the upper portion of Lake Roosevelt. This effort resulted from a petition by the Confederated Tribes of the Colville Indian Reservation. Sediment samples were taken from various portions of the river and tributary locations. No assessment of risk to either humans or the environment (including fish) will be evaluated in this portion of the assessment.

The TGG has done a great deal of the work to summarize the sources of TDG to Lake Roosevelt. An inventory of hydro projects, and water quality monitoring data in Canada have been gathered and shared with the TGG. The next step is to characterize the dynamics of Lake Roosevelt to the degree that questions about the fate and effect of TDG and other pollutants are qualitatively and quantitatively defined. This critical system link cannot be ignored.

Recommendations

1. The Lake Roosevelt Water Quality Council (a diverse local watershed group comprised of Federal, state, Tribal agency, citizens, local government, Canadian agency and industry representatives) in cooperation with the USGS have developed a comprehensive "Lake Roosevelt and Upper Columbia River Contaminant Program: Environmental and Human Health." This four-year, $3.8 million comprehensive investigation is designed to measure and assess impacts of contaminants to the Lake Roosevelt system and it needs to be funded. Tasks in this proposal include: spatial distribution and deposition of trace elements, loading of trace elements and nutrients, reservoir management practices on contaminate transport, sediment quality contaminates in edible fish and fish health.
2. Determine the specific time course of TDG entering Lake Roosevelt for the U.S. and Canadian sources.
3. Determine the specific distribution of TDG in Lake Roosevelt given the complex operations of the reservoir, elevation changes and flows created by the Corps' reservoir management flood control rule curves and flows, and releases related to endangered species recovery of Snake and Columbia river salmon and resident fish species.
4. Determine TDG impacts to wild and sport fish of Lake Roosevelt from incoming TDG in U.S. and Canadian sources.
5. Determine TDG impacts to benthic aquatics of Lake Roosevelt from incoming TDG in the U.S. and Canadian sources.

III.D.6. Mainstem/Systemwide Water Quality Effects on White Sturgeon

The poor reproductive success of white sturgeon in the impounded sections of the Columbia River has been attributed to habitat, flow, and temperature alterations resulting from hydroelectric development, but water pollution could also be a factor. The longevity, feeding habits, and delayed reproductive maturation of this species likely increase the exposure of individuals to persistent bio-accumulative pollutants, such as PCBs, chlorinated pesticides, and chlorinated dioxins and furans which have been detected in environmental samples from the Columbia River (Foster et al. 1999; McCarthy and Gale 1999; US EPA 1992). These chemicals have been shown to adversely affect reproduction and development, but the concentrations causing adverse effects in sturgeon are unknown. In addition, other types of water pollution, such as endocrine disrupting chemicals, have been shown to affect aquatic species in other river systems and sources for these chemicals are in the Columbia basin but have not been measured.

A cooperative study was initiated between ODEQ, Oregon State University, Pacific University, and the USGS Biological Resources Division investigating the occurrence of chlorinated pesticides and PCBs and their effect on reproductive physiology in white sturgeon. Samples from sturgeon were collected from tissues that would likely accumulate these chemicals as well as those linked to reproductive fitness of individual fish. Tissues were analyzed for chlorinated pesticides and PCBs as well as physiological, molecular, and biochemical measures of reproductive physiology. Specifically, chlorinated pesticides and PCBs were measured in samples from white sturgeon gonads in 1996; livers in 1997; and livers, gonads, and cheeks in 2000 and 2001. Biological endpoint samples were collected for plasma reproductive steroids in 1996, 1997, 2000, and 2001; condition factor and liver enzymes in 1997, 2000, and 2001; and plasma triacylglycerides and free fatty acids in 2000 and 2001. Gonad histology was performed for all years, and liver histology was performed in 2000 and 2001.

The chlorinated pesticide DDT and its metabolites DDE and DDD were frequently detected in livers and gonads of reproductively immature Columbia River white sturgeon with concentrations for DDE>DDD>DDT. Tissue concentrations of organochlorines varied with gonad>liver>cheek. Data from 1996 indicated higher levels of DDE in gonads of fish from The Dalles Pool, but the 1997 data showed no difference with Columbia River location (Foster et al. 2001a; Foster et al. 2001b). Organochlorine data for year 2000 collected samples show higher levels at Bonneville Pool (Feist et al. 2001).

Plasma testosterone and 11-ketotestosterone were negatively correlated with liver DDE for reproductively immature males (Foster et al. 2001a). Preliminary data indicates that a cytochrome P450 involved in steroid metabolism may be induced by DDE and could be a mechanism for plasma androgen reductions. This cytochrome P450 could also be involved in the metabolism of reproductive maturation factors. Hepatic EROD activity, an indicator of another cytochrome P450 that is induced by exposure to compounds that bind to the Ah receptor, was elevated in sturgeon from Bonneville and The Dalles pools but was not correlated with chlorinated pesticides or PCBs indicating exposure to other Ah-receptor agonists, such as PAHs, chlorinated dioxins, or chlorinated furans.

Condition factor for fish from Bonneville pool were lower than those for fish from other locations and triacylglycerides were lower in fish from Bonneville Pool (Feist et al. 2001). Condition factor versus total PCBs were negatively correlated. Many factors could be affecting condition factor but Ah-receptor agonists have been shown to adversely affect energetics.

Vitellogenin, the egg yolk precursor protein, is naturally expressed in vitellogenic females but has been shown to occur in males and nonvitellogenic females exposed to xenoestrogens. Some males and reproductively immature females had elevated levels of plasma vitellogenin indicating exposure to estrogenic chemicals.

Gonad histology revealed some fish had intersex gonads (Feist et al. 2001). In addition, gonad histology from several fish showed irregular ovaries and infiltration of muscle into ovarian tissue. The occurrence of this type gonad histology may indicate exposure and effect from environmental contaminants. Liver histology revealed a high incidence of macrophage aggregates and lymphocytes in some fish, again potentially indicating the exposure and effect of contaminants.

These data indicate potential contaminant effects on plasma androgen concentrations and the induction of liver enzymes. Contaminants may also be involved with reduced condition factor and altered gonad development. The contribution of contaminant stress to the poor reproductive success of Columbia River white sturgeon is unknown, but remains a distinct possibility. The multiple stressors of impaired nutritional status, reduced habitat quality, and increased contaminant loading may be working in combination to cause decreased white sturgeon reproduction.

Recommendations

It is essential that the effects of chemicals on white sturgeon reproductive success and the effects of the dams on chemical concentrations of the persistent bio-accumulative pollutants be further examined. The persistent bio-accumulative pollutants are primarily hydrophobic chemicals that are resistant to degradation. Because of their physical chemical properties these chemicals attach to solid particles and bio-accumulate rather than dissolve in water. Therefore, factors that affect suspended solid fate and transport, such as dams, could have an effect on the fate, transport, and bioaccumulation of persistent bio-accumulative pollutants.

The efforts for these studies have collected one of the largest data sets on white sturgeon for organochlorines and reproductive physiology. However, there are several questions that need to be addressed concerning the effects of environmental contaminants on the reproductive physiology of white sturgeon in the Columbia River.

1. The work to date has centered on reproductively immature white sturgeon collected from the commercial harvest. This was an appropriate method for initial data collection, but information is necessary on older reproductively cycling white sturgeon in order to fully assess the potential effects of these environmental contaminants on sturgeon at all phases of reproductive development. Work similar to that conducted on the reproductively immature sturgeon should be conducted on larger reproductively maturing sturgeon. Data collection should continue with the reproductively immature white sturgeon to expand the list of potential contaminant effects and to assist in directing areas of inquiry for reproductively mature sturgeon. Studies of mature and immature sturgeon should evaluate contaminant concentrations in tissues important for reproduction and development of sturgeon. Biological endpoints should be measured in these and other tissues important for reproduction and development to assess reproductive status and effects of environmental contaminants on reproductive physiology.
2. More information is needed on the potential effects of contaminants on sturgeon energetics. There is evidence from other river systems that endocrine disrupting chemicals could be interacting with micronutrients and energetics to affect growth, reproduction, and development. The results to date show correlative evidence for a link between environmental contaminants and condition factor, but additional information on a possible mechanism is needed. Such studies will provide information for determining if environmental contaminants are causing reduced condition factor in sturgeon from some locations or if other factors are playing a primary role.

III.D.7. Water Temperature and Salmonid Migrations in the Mainstem Columbia River

The meandering form, complex channel structure, and broad alluvial valleys seen in naturally flowing large river systems create and maintain a fine-scale pattern of thermal refugia in the riverine environment. Hyporheic flow acts as a temperature buffer in large river systems where variation in river temperature and flow results in differential heat and water storage in alluvial substrates (Stanford and Ward 1993; Brunke and Gonser 1997; Poole and Berman 2001). Complex channel structure, such as undercut banks, backwaters, and oxbows, maintains thermal refugia created by hyporheic flow and cool groundwater springs and seeps by sheltering this thermal habitat from radiant heating and thermal mixing. The Hanford Reach of the mainstem mid-Columbia River is the only remaining free-flowing large alluvial valley on the mainstem system below the U.S./Canadian border. The Hanford Reach supports the furthest inland healthy population of fall chinook salmon (Huntington et. al. 1996). Salmonids are known to seek out thermal refugia to escape stressful water temperatures and conserve energy during holding and migration and research suggests that thermal refugia provides critical habitat for salmonid populations during the warmest times of the year (Matthews et al. 1984; Berman and Quinn 1991; Nielsen et al. 1994; McIntosh et al. 1995; Belchik 1997; Bartholow 1999; Torgersen et al. 1999; Ebersole et al. 2001). Thermal refugia provide protection from extreme winter temperatures as well.

Much of the riverine morphology that creates and maintains thermal refugia has been degraded or eliminated in the mainstem Columbia River basin. 30 major hydroelectric dams impound the mainstem river system. These hydroelectric projects have profoundly altered the natural thermal landscape through flow regulation, inundation of alluvial floodplains, and channel simplification (Allen and Flecker 1993; Coutant 1999; Poole and Berman 2001). Hydroelectric projects are often sited at constricted areas below large alluvial valleys where the new reservoir inundates the alluvial floodplain and flow regulation slows or eliminates the differential exchange of heat and water through the substrate (Ward and Stanford 1995; Coutant 1999; Poole and Berman 2001). Channel complexity is also lost when reservoirs replace the natural shoreline. Other shoreline modifications, such as diking to support railroad and highway beds interfere with tributary and groundwater input into the mainstem Columbia River. These physical barriers may isolate groundwater springs, seeps, and cool tributaries from the mainstem river, reducing or eliminating cool thermal plumes into the mainstem and disconnecting thermal refugia from the larger riverine ecosystem. The degradation and elimination of thermal refugia in the mainstem Columbia River basin is a direct consequence of the loss of thermal buffering capacity, loss of channel complexity, and isolation of thermal refugia.

Historically, the alluvial floodplains and channel complexity of the mainstem Snake and Columbia rivers, along with cool tributary and groundwater inputs, likely provided a broadly distributed and well-connected fine-scale pattern of thermal refugia for resident and migrating salmonids. It is clear that human activities have altered the mainstem Columbia and Snake rivers channel morphology and flow patterns. These anthropogenic changes have likely degraded and eliminated much of the naturally occurring thermal refugia that existed (Li et al. 1995; Torgersen et al. 1999; Poole and Berman 2001). Currently, water temperature issues concerning the mainstem Columbia River basin are primarily focused on large sources of thermal patterns, e.g., releases of cold water from Dworshak Reservoir into the Clearwater

River. The fine-scale mainstem riverine thermal refugia and the critical habitat function it serves to the mainstem aquatic ecosystem continue to go unrecognized.

From an ecological standpoint, the loss of fine-scale thermal refugia may be as critical a temperature problem for native salmonids as altered thermal regimes and radiant heating of reservoirs (Coutant 1999). However, the status and ecological function of thermal refugia in the mainstem Columbia River basin has not received much attention.

The extensive human alteration of the mainstem Columbia River, the natural pattern of fine-scale thermal diversity in large temperate river systems, and the documented thermoregulatory behavior of salmonids indicate this important water temperature issue of the mainstem aquatic ecosystem needs to be addressed.

Recommendations

Identification and protection of existing cold water thermal habitat on the mainstem rivers of the interior Columbia River basin needs to be a top priority. Establishing the use and biological significance of fine-scale thermal habitat to salmonid life history patterns, particularly to stocks with long inland migrations during the warmest months, is needed. Restoration efforts on the mainstem Columbia and Snake rivers may be possible in some areas and could include reconnecting floodplains, reestablishing complex channel morphology, and improvements in existing tributary and groundwater inputs.

1. Estimate historic and current availability of thermal refugia to migrating salmonids using the mainstem Columbia and Snake rivers when water temperatures are warmest in the system.
2. Identification, investigation, and monitoring of thermal refugia in the mainstem Columbia and Snake rivers. Investigations need to include biological, chemical, and physical characteristics of thermal habitat.
3. Use of temperature archive tags and analysis of existing radio-telemetry data to investigate the use of thermal refugia by migrating adult and juvenile salmonids.
4. Bioenergetics modeling to estimate the energetic costs/benefits of various thermal scenarios to migrating adult fish.

III.D.8. CRITFC View of Long-Term Temperature Monitoring

There is a serious lack of temperature data and information throughout the mainstem Columbia and Snake river hydrosystems. These data are important to salmon recovery for several reasons. First, the baseline data will enable regulators to determine where and when temperature violates water quality standards in the mainstem Columbia River. A comprehensive temperature database will also enable fish biologists and managers to better understand the extent and nature of temperature exceedences on adult and juvenile fish passing through the Columbia River hydropower system. In addition, temperature profile data can be analyzed with adult and juvenile radiotelemetry and sonic methods to clarify adult salmonid migration corridors through specific thermal lenses (Karr et al. 1998).

The only mainstem temperature information currently available is real-time data associated with scroll case measurements and monitors associated with TDG monitoring in dam forebays and tailraces. These data, however, do not describe the temperature conditions in reservoirs or at dam passage facilities, yet water temperatures in adult fishways and juvenile bypass systems generally exceed water temperature standards for most of the summer months

(WDFW and ODFW 1991-2001). Studies have indicated significant variation in thermal regimes in adult fishways (Dalen et al. 1996) and variations compared with tailrace temperatures (Corps 1994). However, there is no comprehensive monitoring system at each dam fishway to quantify the extent of the variation. Furthermore, in juvenile passage facilities, there are no comprehensive temperature monitoring systems with the exception of McNary Dam (Hoffarth 2000).

Comprehensive temperature monitoring should be included in the water quality management of the Columbia River. This monitoring should include three major objectives: 1) Installation of a comprehensive, multilevel thermograph system in the lower tributaries and dam reservoirs throughout the Columbia and Snake rivers using the tri-level thermograph system described in Karr et al. (1998); 2) Installation of a specific temperature monitoring systems at all juvenile and adult dam passage facilities in the Columbia and Snake riversand 3) Determination of the occurrence of high water temperature with other stressors that impair biological functions of adult and juvenile salmon.

Recommendations

Objective 1:

1. Characterize temporal and three-dimensional spatial variability of temperature as a function of hydrosystem operations.
2. Establish a quality control plan to calibrate and maintain system accuracy to 98% or above reliability and calibrate instruments on a weekly or bi-monthly basis.
3. Establish a system capable of self-contained data login repository instrumentation that transmits at least hourly gas and temperature data measurement to a control database via telemetry.
4. Post the database on the Internet so that the data are available for real-time management decisions.
5. Use the system to obtain detailed temperature profiles of the forebays and overlay this information with the depth-of-migration information for both adults and juveniles to analyze relationships.
6. Use the data to calibrate temperature models and to predict the outcome of different river management decisions.

Objective 2:

1. Use adult monitoring systems described in Dalen et al. (1995) and juvenile monitoring systems described by Hoffarth (2000).
2. Post data on the Internet so that the data are available for real time management decisions.
3. Use the systems to obtain detailed temperature profiles of the forebay and overlay this information with the depth-of-migration information for both adults and juveniles to analyze the relationship.
4. Calibrate temperature models with data obtained from the system. The model results can predict the outcome of different river management decisions.

Objective 3:

1. Monitor water quality in the vicinity of known major point source discharges to assess the spatial and temporal occurrence of thermal migration blockages.
2. Monitor low dissolved oxygen concentrations and concentrations of known water quality constituents that exacerbate the detrimental effects of high water temperature.
3. Assess the influence of temporal and spatial alterations to the thermal regimes of the Mainstem Columbia and Snake Rivers to salmon life stages and ecosystem processes.
4. Assess the use of marginal habitats by adults or juveniles during their migrations or rearing phases, the direct influence of water temperature on these life stages (mortality, growth), and the indirect influences of water temperature on these life stages via effects on the food base.
5. Assess the use of mid-channel habitats by adults or juveniles during their migrations or rearing phases, the direct influence of water temperature on these life stages (mortality, growth), and the indirect influences of water temperature on these life stages via effects on the food base.
6. Assess the temperatures and discharges of major tributaries to the Columbia and Snake Rivers for purposes of constructing heat budgets of these river systems.
7. Assess the spatial distribution of thermal refugia along the mainstem channels, including off-channel areas and lower tributary reaches.
8. Model expected growth rates of rearing juveniles based on probable thermal history and food availability and compare with actual growth rates and food availability by habitat type.
9. Assess the frequency and geographic extent of warmwater salmonid diseases in relation to thermal exposure history.
10. Assess the ability of water temperatures in excess of 12°C for steelhead and 15°C for coho and chinook to impair or reverse smoltification indices. Investigate influences of maximum and mean daily temperatures, and daily duration of temperatures exceeding critical thresholds in fluctuating thermal regimes.
11. Assess the effect of thermal migration blockages or high temperature migration environments on population productivity indices. These investigations would include time length of migration delay relative to physiological indicators of adult senescence, time and distance to spawning grounds, and ability to locate mates; thermal effects on eggs (survival, developmental abnormalities, fertility) held in mature females during migration vs. pre-spawning phase; degree of bioenergetic depletion under different thermal migration scenarios; fecundity or egg size under different thermal migration scenarios for various salmon species and age classes; influence of maximum vs. mean daily temperature on initiation of spawning; survival of eggs deposited during earliest spawning period (i.e., warmer conditions) vs. later spawning periods (cooler conditions); influence of delayed spawning on emergence timing and survival relative to timing and survival of adults spawning under historic conditions.

III.D.9. Mainstem Water Quality Data Management Needs

Currently there are multiple water quality databases used by agencies with management responsibilities for the Columbia and Snake rivers (see Table 8: Water Quality Databases for the Mainstem Columbia and Snake Rivers). These databases sometimes are fragmented and out-of-date due to the differing missions of the database creators and the varying, often insufficient, resource levels. Some of the databases are integrated across state and subbasin lines and some are accessible via the Internet. Additional databases are being created by agencies, Tribes, and contractors working on specific research, monitoring and evaluation, and implementation projects.

Lack of common data elements, exchange formats, and agency policies on disposition of data hinder integration and accessibility. As a result, some water quality data will be lost or underused. Most projects which generate data under the NWPPC's Fish and Wildlife Program lack metadata and there is a Region-wide need for common metadata forms. Metadata is simply descriptive information, a common set of terms and definitions used when documenting data.

Problems with water quality data management are similar to the common data management problems addressed in the Mainstem /Systemwide Summary document, Data Management in Support of the Fish and Wildlife Program. The report also notes the modernization efforts spurred on by rapid advances in technology.

Management of water quality data (chemical, biological, temperature, sediments, and sometimes habitat data) needs to be integrated and the data made accessible to potential users. Integration doesn't require storage in a single place as long as the managers of distributed servers adopt common data elements and exchange formats. The Region can use selected portions of the National Water Quality Monitoring Council's Common Water Quality Data Elements, available at: http://wi.water.usgs.gov/pmethods/elements/elements.html.

Metadata forms using these common elements will aid the Region to adhere to the Congressional intent of developing water quality data comparability among Federally-funded agencies and their program contractors and partners. Alternatively, the data producers can use state-based (if regionally compatible) approaches such as that being explored by Washington's cross-agency Comprehensive Monitoring Strategy.

Technology has improved to the extent that all databases developed from BPA-funded projects and those of nearly all water quality managers in the Columbia River basin can be made accessible to users via the World Wide Web. If a sufficient level of data quality assurance is agreed to at the beginning of a project contract, project sponsors may be able to add their data to the data management systems of the state water quality agencies (such as Washington Ecology's EIM system and Oregon's LASAR) or to EPA's national STORET system. This will produce efficiencies of scale and provide the state water quality agencies with more accurate ambient monitoring data. Such data will support listing of water bodies under Section 303(d) of the CWA. Project sponsors may be able to contribute fish-related water quality data to state fish and wildlife agencies or to projects such as StreamNet, which manages Columbia basin fisheries data and some water quality data from the states and Tribes.

Data exchange formats and improved data quality assurance make the data easier for regulators and researchers to apply. Tools exist that can gather data from multiple databases at websites. These applications, such as the RAINS system developed by EPA Region 10, can pass the data query to any or all sites that have water quality data, retrieve the data, and graph or map the data. The University of Washington's DART project (see table and the data management program summary) produces applications that allow users of the mainstem and tributary CROHMS TDG and temperature data to view these data in several graphical formats. Such tools improve analysis of the data and foster decision-making.

Substantial resources are being applied to solving the ESA and CWA water quality problems on the mainstem. Efficiencies in funding, analysis, and problem solution can be gained through improved data management based on integration, compatibility and accessibility.

Recommendations

1. Building on existing water quality databases and data management systems, data generators should integrate data from Federal, state, tribal, and local agencies and make the data Web-accessible. Avoid duplication and share resources and data.
2. Ensure that any BPA-funded monitoring projects which measure TDG, temperature, or other water quality parameters related to the hydrosystem are comparable with those of the Corps, USBR, USGS, CRITFC, and state agencies working in the same reaches.
3. The Region should strive for common protocols for management of water quality data. These protocols would include 1) specification of necessary variables to observe – if a study must collect a specific set, make sure the full set is included to broaden use of the collection effort; 2) specification of metadata required to characterize data, inform users, and facilitate integration of data into a regional resource; and 3) specification of required repositories, required submission deadlines, etc., with methods of confirming submission. Several agencies listed in the table of water quality data providers have developed such requirements for their own programs.
4. The Fish and Wildlife Program needs to recover water quality and biological data from currently or recently funded BPA projects (at least last 2-3 years) before they are lost. The Program needs to set the standards for future work. To retrieve past data and ensure future quality, create water quality data SWAT teams that will work with project sponsors to assemble and upload these data to BPA-approved regional data management systems. These data SWAT teams should be managed/advised by entities with recognized water quality data management expertise, such as USGS, EPA, coalitions of state agency data experts, or major contractors with such expertise.

Table 8. Water Quality Databases for the Mainstem Columbia & Snake Rivers

Project Name	Data Manager	Identifier / BPA Project #	Web URL	*Used For*	*Database Format*	Comments
CROHMS	USACE	N/A		TDG, Temperature, and other WQ parameters from Corps - operated dams		Real-time data in DART; system will be updated
Total Dissolved Gas Reports	USACE - NPR	N/A	http://www.nwd-wc.usace.army.mil/report/tdg.htm	TDG data	Spreadsheets?	Part of CROMHS
Data Access in Real Time (DART)	University of Washington Data Management Center	BPA #9601900	http://www.cbr.washington.edu/dart/ http://www.cqs.washington.edu/dart/hgas_com.html			Second Tier Database Support for Ecosystem Focus
Northwest Regional Temperature Data Analysis page (DART)	University of Washington Data Management Center	BPA #9601900	http://www.cbr.washington.edu/data/Streams/	Graphical display of temperature data	Application -- uses mainstem and tributary temperature databases	
EPA Region 10 Temperature Data Access Page (ID, OR, WA)	U.S. Environmental Protection Agency - Region 10	N/A	http://www.epa.gov/r10earth/data/sdata/sdatasub.htm		Accessible by 8-digit HUC code and downloadable as dBase (.dbf) or Excel (.xls) files	Not actual WQ data but list of contacts
EPA-STORET	U.S. Environmental Protection Agency	N/A	http://www.epa.gov/storet/			

Envirofacts - Warehouse	U.S. Environmental Protection Agency	N/A	http://www.epa.gov/enviro/html/ef_overview.html			
Lower Columbia River Dissolved Gas Monitoring Network	United States Geological Survey	N/A	http://oregon.usgs.gov/projs_dir/pn307.tdg/	Provisional Realtime WQ data		USACE is cooperating agency
NWIS-WEB	United States Geological Survey	N/A	http://wa.water.usgs.gov/realtime/nwisweb.html http://water.usgs.gov/or/nwis			
NASQUAN – National Stream Quality Accounting Network	United States Geological Survey	N/A	http://water.usgs.gov/nasqan/			
National Water Quality Assessment (NAWQA) Data Warehouse	United States Geological Survey	N/A	http://infotrek.er.usgs.gov/pls/nawqa/nawqa.home http://water.usgs.gov/nawqa/			
WDOE – River and lake monitoring stations	Washington Department of Ecology	N/A	http://www.ecy.wa.gov/programs/eap/fw_riv/wa_rvlks.html			
Environmental Information Management (EIM)	Washington Department of Ecology	N/A	http://www.ecy.wa.gov/services/as/iip/eim/index.html			Currently available within WDOE; external access soon.
Laboratory Analytical Storage and Retrieval Database (LASAR)	Oregon Department of Environmental Quality	N/A	http://waterquality.deq.state.or.us/wq/lasar/LasarHome.htm http://waterquality.deq.state.or.us/wq/lasar/StationLocatorBasins.asp			Air and water quality data with CAS No. and No. samples. Surface and ground-water quality monitoring data and station info by subbasin or watershed.

StreamNet – The Northwest Aquatic Information Network	Pacific States Marine Fisheries Commission (PSMFC) and others*	BPA #8810804	http://www.streamnet.org/online-data/temperature1.html	Temperature, Including a database compiled by McKenzie and Laenen for EPA Contract	spreadsheets	*Includes CRITFC, IDFG, ODFW, WDFW, MFWP, USFWS
Grant Co. PUD	Grant County PUD	N/A	http://www.gcpud.org/stewardship/waterquality.htm	WQ data for dams operated by the PUD	MS-Excel spreadsheets	
Northwest River Forecast Center – Hydrometeorological	NOAA/NWS - NWRFC	N/A	http://www.nwrfc.noaa.gov/data/data.shtml	Includes meteorological info to support WQ models		
Current Hydrologic Conditions	NOAA/NWSHIC	N/A	http://www.nws.noaa.gov/oh/hic/conds.html	Links to NOAA hydrologic forecasting pages		Not sure this leads to relevant data on actual precipitation or other WQ parameters used in models -- check

5. BPA should, through its contract conditions, or the NWPPC, through policy guidance, should foster submittal of water quality data to the national EPA-STORET system or to the individual STORET–compatible state water quality systems such as WDOE's EIMS or ODEQ's LASAR system. Fish-related water quality data can be submitted to Streamnet for warehousing or to the appropriate Federal, state, or Tribal agency with Web-accessible, STORET-compatible systems.
6. Encourage development of applications that improve analysis and presentation of water quality monitoring data. Stress tools that will be in the public domain or likely to have long-term support due to wide acceptance.
7. Agencies involved with the NWPPC's Fish and Wildlife Program should collaborate more with external (non-Fish and Wildlife Program) water quality data managers for the mainstem Columbia and Snake rivers. Partners may include EPA, NMFS, USGS, PUDs, private industry, and state water quality, natural resource and agricultural agencies.
8. To enhance QA/QC for mainstem temperature and TDG monitoring data, support the installation of additional meteorological stations near the mainstem. Document locations for additional Class A weather stations, if needed.
9. Coordinate with the Corps in its upgrade of the CROHMS data management system to a STORET compatible format. This upgrade should be a high priority for all work on the mainstem since that system contains the largest amount of water quality data for the hydrosystem.

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