COLUMBIA RIVER INTER-TRIBAL FISH COMMISSION
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February 7, 2003

Mark Walker
Public Affairs
Northwest Power Planning Council
851 S.W. Sixth Ave.
Suite 1100
Portland, OR 97204-1348

Re: Mainstem Amendment Document

Dear Mr Walker:

Thank you for the opportunity to submit comments and recommendations on the Council's draft amendment to the mainstem provisions of the Council's Columbia River Basin Fish and Wildlife Program. These comments and recommendations are submitted at the direction and on behalf of the Commission's member tribes.

The Commission continues to support the recommendations it provided to the Council on June 15, 2001 for amendment to the Council Program, with certain refinements related to reservoir operations. Since submitting those recommendations we have coordinated with other fish and wildlife managers in the basin to share information concerning possible alternative operations of the Columbia Basin's dams and reservoirs. These efforts have confirmed our view that successfully meeting both the reservoir related needs of resident fish and the downstream survival objectives of anadromous fish will require modifications to flood control management and dam configuration.

Our comments are provided in a series of appendices to this letter, which address different issues in the rulemaking. These are as follows:

1. Section by Section Comments and Recommendations on the Draft Amendment.

   Our section by section review (Attachment 1) provides comments and recommendations on the Council's draft amendment document. The review sets forth particular flow, spill, and transport operations, which are refined from our June 15, 2001 recommendations and based on the most recent and best scientific information available. The review also addresses rebuilding objectives, lamprey and sturgeon measures, water quality needs, management and oversight of the Fish Passage Center, and regional coordination needs.

2. Presentation and Analysis of Alternative System Operations.

Attachment 2A is an analysis of the CRITFC recommended system operations in comparison to the operations in the proposed amendment and those contained in the 2000 FCRPS Biological Opinion of NOAA Fisheries. This analysis was prepared by CRITFC staff using the GENESYS modeling tool also used by the Council. Attachment 2B is a memorandum prepared by David Benner of the Fish Passage Center comparing the Council's analysis to a similar analysis conducted by the Bonneville Power Administration. These analyses describe the various changes in flows that are likely to result if the measures in the Draft Amendment were implemented by system operators.

Generally speaking, during average and below average years the measures in the Draft Amendment would result in significantly lower flows from April 15 to August 31 compared to the measures contained in the FCRPS Biological Opinion. During certain periods in this time span severe decreases in flow would be expected to occur. It is our opinion that such changes in flow regimes are likely to occur should the flow measures in the draft be adopted and implemented. In contrast, the CRITFC recommendations generally increase flows during this time period and generally result in fuller reservoirs when compared to FCRPS Biological Opinion operations. The CRITFC recommended operations are specified narrative description and in GENESYS modeling runs, which we are providing with these comments.

3. An Assessment of Impacts of Alternative System Plans on Snake River Spring Chinook.

We have provided two model-based analyses for your consideration. The first analysis, (Attachment 3A) in our opinion, is the more accurate assessment of biological effect and was carried out using a peer-reviewed and recently calibrated passage model, which includes a flow-survival relationship. The output of this model is then incorporated into a life-cycle model. This modeling system addresses delayed mortality associated with in-river migration and transportation. The results of this analysis show that for the BiOp and Council draft measures the time to extinction for the Marsh Creek spring chinook index stock is approximately 25 years. If the CRITFC recommendations including breaching the Snake River dams are implemented, we would expect an 80% or better probability that this population of chinook would double in 25 years with zero probability of extinction in 25 years. If the CRITFC recommendations for system operations only (without breach) are implemented, the time to extinction increases to about 37 years.

The second model analysis (Attachment 3B) used the SIMPAS model, which provides something of a "snapshot" view of the effects of alternative passage measures on juvenile salmon migration. SIMPAS is not sensitive to temperature or flow, does not address differential delayed mortality, and suffers from a number of other limitations that are described in the attachment. However, our application of the SIMPAS model confirms our view that the Council amendment will decrease in-river juvenile survival compared to the BiOp, whereas the CRITFC recommendations would increase in-river

juvenile salmon survival compared to the BiOp. Moreover, the Council amendment would significantly increase the number of juvenile salmon transported. Because of recent scientific information indicating that adult returns of transported wild chinook are less than returns of in-river migrants, we do not believe that the Council amendment is biologically warranted.

4. Controlled Spill and Dissolved Gas Risk Assessment.

The Draft Amendment hypothesizes adverse effects on adult salmonid passage at the dams related to controlled spills needed to assist juvenile migrating salmon. We disagree with the Draft's assertion. Reductions in the levels of managed spill to reduce the incidence of gas bubble trauma (GBT) in juvenile or adult salmonids are not warranted. This issue has been carefully considered by the tribes, other fishery managers, and state water quality agencies. For juvenile salmonids, the incidence of severe gas bubble trauma is demonstrated when total dissolved gas (TDG) concentrations approach 130%, which is far beyond the levels of TDG resulting from the spill management recommendations of the tribes. Adult salmonids find depth compensation protection from gas bubble trauma and exhibit no symptoms of trauma at concentrations of 120% or below. Managed spill remains the safest route of passage for juvenile and adult downstream migrating salmonids. Attachment 4 presents a risk-benefit analysis considering, spill, TDG, GBT, and adult and juvenile salmon survival.

5. The Best Available Scientific Information Documents the Existence of a Flow-Survival Relationship for Juvenile Salmonids.

Attachment 5 presents a review of historic and recent information on the effects of flow on juvenile salmonid migration timing and survival, including survival to adulthood. The BiOp flow targets appear to represent a minimum needed to maintain the Snake River spring summer chinook populations for average to good ocean conditions and provide inadequate protection for poor ocean conditions. The Council's proposed relaxation of spring flow targets would increase water travel time and reduce protection against population declines and the likelihood of rebuilding spring and summer chinook stocks. Juvenile migration conditions and ocean climate conditions were both influential in explaining patterns of SARs in Snake River spring and summer chinook and steelhead. Relaxation of Spring flow objectives would likely decrease the SARs of wild Snake River spring and summer chinook and steelhead.

6. Fish Passage Center

We endorse the recommendations of the Columbia Basin Fish and Wildlife Authority with regard to the oversight and management of the of the Fish Passage Center. As you know, the Center is partially funded by BPA and partially funded by the state and federal fish and wildlife agencies. Attachment 6 to our comments and recommendations is a recent report regarding Fish Facilities Inspections prepared by the Fish Passage Center. This activity is one of the many activities carried out by the Center. We offer

this report to document one of the important and non-controversial technical services the Center offers to the region. We do not support transferring the oversight and management of the Fish Passage Center to the Council, since among other things the Council is not engaged in day-to-day management of system operations. The tribes and fishery agencies are so engaged and have designed their activities in this regard based continued availability and uninterrupted access to the Center's technical services.

We hope to engage the Council in consultation on our comments and recommendations before the Council adopts final mainstem amendments. For several reasons, we request the opportunity in this consultation or otherwise to provide additional information to the Council:

First, it is our understanding that the Independent Scientific Advisory Board will soon publish a draft review of information on flow and survival and that the ISAB will seek comments on their draft to be submitted by February 25, 2003. We would like to provide such comments and have those comments considered in your record.

Second, we are anticipating that the Council staff may publish additional hydropower operations simulation modeling. If so, we would appreciate the opportunity to review that modeling, compare it to our own, discuss the modeling with Council staff, and present additional information to the Council.

Third, nearly two years have lapsed since we submitted our recommendations to the Council. About nine months ago, the Council began earnest consideration of alternative mainstem measures. Most, if not all, of these alternatives appear to have been created by the Council staff and none of which reflect CRITFC's original recommendations. We are concerned that due to the passage of time, the Council has overlooked CRITFC's recommendations in its consideration of alternatives.

Thank you, for your consideration of our comments and recommendations including each of the attached documents. We look forward to discussing these with you.

Sincerely,

Donald Sampson
Executive Director

cc: CBFWA

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Section by Section Comments
on the Northwest Power Planning Council's
Draft Amendments to the Mainstem Provisions
of the Columbia Basin Fish and Wildlife Program
February 7, 2003…***corrected on February 14, 2003***

Page 6. Addressing the Needs of Resident and Anadromous fish.

We support CBFWA's comments on meeting the needs of resident and anadromous fish. We are concerned that power interests have put forward false trade-offs between resident and anadromous fish. We believe that trade-offs between resident and anadromous fish, to the extent such trade-offs exist, should be decided upon and managed by the fish and wildlife managers, not by power interests or the Council.

Page 7. Power Supply Analysis.

CRITFC generally agrees with the conclusions articulated by Council staff. We are disappointed however that the analysis does not appear to have considered CRITFC's mainstem recommendations. For instance, none of the eleven alternatives considered addresses the CRITFC's recommendation for refilling reservoirs by May 31. Nor do any of the alternatives appear to consider CRITFC's proposal to increase spill levels. We find this surprising since we have provided GENESYS output of the CRITFC recommendations to Council staff. We are also transmitting our most recent GENESYS model results for your consideration.

Based on our application of GENESYS, it appears that the NPPC plan offers, on average, a 468 MW increase in total annual generation, relative to the Biological Opinion and would produce $10 to $13 million per year or cost $29 million per year, depending on the water year. [1] CRITFC's plan, on average, produces 243 MW less in total annual generation, relative to the Biological Opinion and would produce $17 million per year (or $255 million in an unusual power market such as 2000) or cost $32 million per year, depending on the water year, relative to the Biological Opinion spill values. CRITFC's plan gives more generation in June, July, later half of August, and September, relative to the Biological Opinion. The NPPC plan shifts generation from spring and summer to winter (December through March) with a 100 MW to 1300 MW reduction in generation during spring and summer months. We note that our results

[1] Based on the Council staff's 0ctober 23, 2002 version of its GENESYS modeling analysis. We are uncertain which version of the Council staff's GENESYS modeling analysis is reported in the draft amendment document.

appear to be somewhat different from those presented by the Council. We believe that this is primarily attributable to differences in interpretation of the Council's proposal and Biological Opinion and the choice of input parameters to reflect these plans (e.g., we assumed that the Council draft was based on 115% TDG limits and elimination of the April 10 refill requirement, Alt. D). However, as noted in our January 21, 2003 letter to the Council, we are still awaiting receipt of the Council's revised GENESYS analysis.[2] We look forward to reviewing the update analyses and providing further analysis and comment to the Council.

Page 9. Environmental Variation

We support the Council's statement about restoring ecosystem functions:

> The long-term vision of the Council's 2000 Fish and Wildlife Program is for a Columbia River Basin ecosystem that sustains abundant, productive and diverse communities of fish and wildlife, mitigating across the basin for the adverse effects to fish and wildlife caused by the development and operation of the hydrosystem and providing the benefits from fish and wildlife valued by the people of the region. This ecosystem provides abundant opportunities for tribal and treaty right harvest and for non-tribal harvest of fish and wildlife, and for the recovery of fish and wildlife affected by the operation of the hydrosystem. <u>This ecosystem is ecologically resilient and able to maintain its characteristics in the face of environmental variation.</u> This program is to be "habitat-based."

We recommend that the Council include the underlined statement in the Program. We are concerned that the region could be misled into complacency because of recent upswings in ocean productivity. Ocean productivity is known to be cyclical and the River Basin's ecosystem must provide sufficient productivity for periods of low ocean productivity. For example, the base period for common year effects (1952-1995) included a period of above average ocean survival years (1952-1975) and a period of below average ocean conditions (1976-1995). The sensitivity of population growth is addressed in the paper entitled "An Analysis of "All-H" actions for Snake River spring/summer chinook stocks using the PATH Life-Cycle Model, and a Preliminary Feasibility Analysis of those Actions," submitted with our original recommendations.

Page 9. Meeting Water Quality Standards

Water quality in the mainstem Columbia and Snake Rivers has continued to deteriorate since the establishment of the last Council Fish and Wildlife Program in 1994. McCullough

[2] In our letter we noted that it was important to have regional agreement on the hydrological modeling data inputs and results, because the hydrological modeling was the foundation of biological and economic comparisons between the Council's proposed amendment and other regional proposals. At that time, several serious mischaracterizations were evident in the Council staffs' model assumptions, and some of these, to the best of our knowledge were not resolved by the comment deadline to the amendments. These issues must be resolved to allow an authentic comparison between the Council's proposed amendment and the tribal and other regional proposals for the mainstem amendment process.

(1999) notes that mainstem temperatures often exceed tolerance ranges for salmon and the critical thermal maximum is often reached. Cumulative exposure of salmon to high temperatures creates stress, reduce growth, consume critical energy reserves, can reverse the smoltification process and leads to disease infestations (e.g. *columnaris*). Further, temperature increases significantly increase predator consumption rates. The mainstem is now listed as water quality impaired for temperature and dissolved gas and on the 303d list for the states of Washington, Oregon and Idaho. A temperature model created by EPA has been used to determine cumulative temperature loading maximums for individual dams in the Columbia and Snake river hydrosystem (Yearsley 2001). In response to the 303d listings and using the temperature model, EPA and the states have developed a total maximum daily load allocation (TMDL) that will limit additional pollution loads into the river and require the hydrosystem operators to comply with an implementation plan to meet TMDL standards.

The Council should fully support the draft TMDL for mainstem temperature and total dissolved gas currently developed by EPA, and the implementation plans that will provide temperature relief in the mainstem. Among other things, the Council should adopt measures in these plans for: 1) operations such as modification of flood control to increase volumes of cool water releases from upstream storage reservoirs, 2) spill to keep juveniles out of bypass and transportation systems that are warmer than the ambient river at depth, 3) structural modification for temperature regulation in fishways, 4) comprehensive temperature monitoring and, 5) addition of dissolved gas structures on dams. The Council should strongly support these and other specific and detailed measures as necessary to meet water quality standards for total dissolved gas and temperature as critical to the enhancement of mainstem habitat and protection of the beneficial use, anadromous fish as they pass through dams and reservoirs. Further, the Council should support current water quality standards that are based upon a Class determination instead of a Use-based determination.

Non-point and point source pollution from agricultural runoff, dredging, industrial plants and municipal sources is a serious problem in the mainstem Snake and Columbia Rivers. NMFS studies indicate that juvenile salmon in the Lower Columbia River and estuary have body burdens of toxic substances that are already approaching threshold levels. Studies by Oregon State University indicate that even small levels of toxics can compromise behavior and physiological processes for juvenile salmon (Ewing 1999). The Council should adopt measures that require the Corps and others to establish baseline monitoring, toxicity and bioaccumulation evaluations and risk assessment protocols before additional dredging or NPDES permits are issued and implemented.

Page 11. Overarching Objectives and Priorities.
Doubling, Not Just Recovery

In 2000, the Council revised their Fish and Wildlife Program to include an interim restoration goal of increasing the anadromous fish runs above Bonneville Dam to 5 million fish by the year 2025. This is sometimes referred to as a “doubling goal” since it is approximately

twice the run size which existed at the time the Council was formed in 1980. Balancing actions to achieve this goal must account for two constraints.

First, achieving this goal will require a sustained average population growth rate each generation of from approximately 10% (for coho with a 3-year life cycle) to approximately 15% (for chinook populations with a 5-year life cycle). Restoration efforts in the early years of this 25-year period must, therefore, emphasize strategies with a short time to pay-off (e.g. hydropower improvements). Longer-term strategies such as habitat restoration (with a 5 – 10 year or longer time to pay-off) can contribute to achieving the goal in later years.

We support the Council's recognition of a 2% to 6% smolt to adult survival rate (SAR). However, we believe that the amendments must do more than "contribute" to this rate of survival. SAR's associated with spring and summer chinook replacement during the 1970 and earlier out-migrations from the Snake River (prior to most of the Snake River dams) were in the range from 3.2-6.1%. (PATH, 1997) Currently Snake River SARs are averaging approximately 0.5%. In contrast, spring chinook SARs for the Deschutes and Yakima Rivers above only two and four dams respectively tend to be at or above 2% regularly. Neither of these stocks is subjected to mass transportation. In fact, the SARs of Snake River spring and summer chinook appears to be inversely related to the proportion of the run transported (see Attachment 5 pp. 44-46). We recommend and continue to support establishment of an objective of 2% to 6% SAR for hydropower operations and configuration.

Page 16. Lamprey

We recommend that the Council include the following measures in the Program for Pacific Lamprey.

- The Council should instruct the Corps, BPA and the Mid-Columbia PUDs, in consultation with tribes and state and federal fishery managers, to fund collaborative projects that develop lamprey supplementation research, methods and programs.

- The Council should instruct the Corps, in consultation with the tribes and state and federal fishery managers, to reinstate funding to complete adult and juvenile lamprey passage research as a high priority. The Corps should implement feasibility studies to install promising modifications to adult fishways to facilitate adult passage, and increase juvenile lamprey survival through dams and should evaluate the success of such modifications. Further, the Council should instruct the Corps to fund additional operations and maintenance procedures, contained in tribal and agency comments to the Corps annual fish passage plans, which would avoid lamprey kills from dewatering fishways and other operations. In addition, the Council should recommend that the Mid-Columbia Public Utility Districts, in consultation with tribes, state and federal fishery managers, to fund similar research to facilitate adult and juvenile lamprey passage through their hydroprojects.

Pacific lamprey are highly regarded culturally and religiously by Native American tribes. Former lamprey abundance provided both tribal and non-Indian fishing opportunities throughout Columbia River Basin tributaries. For example, significant lamprey collection at Willamette Falls for fish food processing in 1913 was documented at 27 tons (CRITFC 1999). Commercial fishermen in the 1940's harvested 40 to 185 tons annually (100,000 to 500,000 adults) at Willamette Falls for use as vitamin oil, protein food for livestock, poultry, and fish meal.

Along the Pacific coast, Pacific lampreys are believed to migrate into freshwater and move upstream to spawn from May to September, overwinter, and spawn in early spring the following year (Beamish 1980, Beamish and Levings 1991). In the Columbia River Basin, data from trapping efforts by the National Marine Fisheries Service (NMFS) at Bonneville Dam suggest Pacific lampreys move upstream to spawn from May to October, with the run peaking in mid-July (Vella et al. 2001, Ocker et al. 2001). While NMFS' research has shown that hydroelectric projects can pose significant passage constraints for Pacific lampreys (Vella et al. 2001, Ocker et al. 2001), details about migration behavior and timing in the CRB are still nearly unknown, including rate of movement through the mainstem Columbia River, timing of movement into tributaries, rate of movement in tributaries and habitat preferences during migration.

Although adult lamprey counting at mainstem Columbia and Snake River dams is not standardized, population trends indicate precipitous declines (Table 1). Based on 1997 fish ladder passage estimates, there was a 65% drop in Pacific lamprey abundance between Bonneville (Columbia River km 235) and The Dalles (Columbia River km 308) dams, with another large drop (72%) between John Day (Columbia River km 347) and McNary Dam (Columbia River km 470) counts. Passage over upriver dams in the Snake and Columbia rivers in 1997 was low. Only 3% of the Pacific lamprey that crossed Bonneville Dam were counted at Lower Granite Dam (Snake River km 173) and approximately 6% crossed Wells Dam (Columbia River km 830).

Table 1. Comparison of Historic and Recent Passage Counts of Adult Pacific Lamprey at Columbia and Snake River Dams (from CRITFC 1999)

Dam	Former Counts	1997 Counts
Bonneville	350,000 in early 60's	22,830
The Dalles	300,000 in early 60's	14,835
John Day	----	14,845
McNary	25,000 in early 60's	4,213
Ice Harbor	50,000 in early 60's	1,454

Lower Monumental	----	217
Little Goose	----	245
Lower Granite	----	1,274
Rock Island	----	2,321
Rocky Reach	17,500 twice in 60's	1,405
Wells	----	773

Current knowledge of habitat use of juvenile Pacific lamprey is mainly limited to tributaries of the Columbia and Snake Rivers (Kan 1975; CRITFC 1999). To date, studies of the use of mainstem habitats have been limited to adult and juvenile migration behavior and dam passage effects (e.g., Starke and Dalen 1995, Moursund et al. 1999, 2000). One reason for the paucity of data on juvenile habitat use is that few comprehensive fishery surveys have been conducted with the mainstem Columbia and Snake Rivers.

There are a few known documented accounts of juvenile lamprey habitat use in mainstem reaches since the period of hydroelectric development (i.e., 1910 to 1968). These observations occurred when water surface elevations were rapidly lowered via manipulation of base flows by hydroelectric dams. For example, investigators documented several hundred juvenile lamprey emerged from the gravel near river km 566 and approximately 40 near river km 555 during a low flow test involving the Hanford Reach in early April 1976 (Page 1976). The arrival of ammocoetes in the collection system of Little Goose Dam suggests that some rearing (and possibly spawning) of lamprey in the tailraces of mainstem Snake River dams (BPA et al. 1994). This premise was substantiated by the report of Dauble and Geist (1992) that several juvenile lamprey were exposed during the test drawdown of Little Goose and Lower Granite dams in March 1992. Recently, investigators observed juvenile lamprey in a gravel bar downstream of Wanapum Dam (Geoff McMichael, PNNL, personal communication, April 2002). Two common features of mainstem habitats where juvenile lamprey are known to rear include a low gradient shoreline and gravel/sand substrate.

Habitat requirements of Pacific lamprey share several common features with salmonids. Both spawn in areas of relatively high velocity, are nest-builders, and eggs develop in the substrate. One importance difference is that juvenile salmon emerge from redds soon after they hatch and rear along the shoreline until they migrate to the ocean during the first or second year of life. In contrast, larval lamprey or ammocoetes burrow into the substrate downstream of the nest after hatching, where they remain and develop for up to 6 years (Scott and Crossman 1973). At transformation, typically at stage 6 or as “young adults,” they move out of their burrow and begin their migration downstream to the Pacific Ocean. While substrate composition of salmon and lamprey redds are different, adequate intergravel flow (a characteristic of alluvial habitats) is

important for the survival of both taxa during their early life history development period. Thus, lamprey would benefit if additional mainstem riverine habitat were created for fall chinook salmon via manipulation of the current hydropower system.

Wide alluvial floodplains, once common in the Columbia and Snake rivers, are largely eliminated and fragmented because of extensive hydroelectric development. Remaining mainstem riverine habitats are restricted to the Hanford Reach of the Columbia River, Hells Canyon in the Snake River, and short sections ~2-5 km downstream of hydroelectric dams (Battelle and USGS 2000). This change suggests that one factor leading to the decline of Pacific lamprey is loss of mainstem riverine habitats for spawning and/or juvenile rearing.

Juvenile lamprey, or ammocetes, are small enough so that they may pass thorough tributary irrigation diversion screens that would restrict juvenile salmon passage. However, by the time they begin their seaward migration, they can become impinged upon turbine intake screens, particularly extended length submersible fixed bar screens (ESBS), installed during the 1990s at most Corps of Engineers dams with screen bypass systems. This problem was first identified in 1995 when test ESBS screens were lifted out of the turbine slots and dozens of lamprey were found impinged between the screen wedge wires. Subsequent studies by Batelle NW Laboratories (Moursund et al. 2002) indicated that juvenile lamprey are weak swimmers and cannot resist turbine intake velocities, with 70-90% of test fish becoming impinged on the screens at test velocities less that actual field velocities. They also found that juvenile lamprey, ammocetes, had the tendency to use their tails for locomotion and then became permanently wedged in the screens.

Another study at McNary dam indicated that of 700 lamprey released, only five were detected at John Day dam. Until recently, the common operation of the Corps has been to sweep impinged ammocetes from the screens so that they can pass through the turbines. Restrictions on tag size has thus far prevented survival tests for lamprey, although tags are current being developed for these studies. Recent work by the Corps has resulted in smaller gaps between wire wedges on the screens to reduce ammocete impingement.

Migration and survival studies have been conducted for adult lamprey since 1997. Radio-telemetry techniques have been utilized to track adult passage thorough the Lower Columbia River dams. Vella et al. (2001) noted that of 130 adults detected at the Bonneville Dam tailrace, only 29 were detected at The Dalles and only three successfully passed over John Day. Particular problem passage areas were identified in the adult fishways. They included passage over diffuser gratings, high velocity areas such as junction pools, fish counting windows where lamprey were discouraged from climbing count windows due to restricted visibility necessary for counting, and areas around picketed leads, vertical slots in fishway entrances and cracks in the fishways themselves. The Corps funded research in 2001 and 2002 to attempt to identify structural remedies for problem areas in fishways. Stansell (2002), Moser et al. (2002) and Daigle et al. (2002) devised structural alterations in the Bonneville Dam fishway to facilitate passage, with plate over diffuser areas, modification of head differentials over weirs and wall dividers to adjust pool velocities showing promise.

Adult lamprey can also be trapped below floor diffusers during fishway dewatering for maintenance. In November 2002, over 5,000 lamprey were trapped at John Day in this fashion, and of these about 1,200 were lost due to human error. Unfortunately, for 2003, just when adult passage solutions appear at hand, the Corps terminated all research funding for juvenile and adult lamprey passage in their Columbia River Fish Mitigation Program that annually receives about $80-100 million from Congressional appropriations.

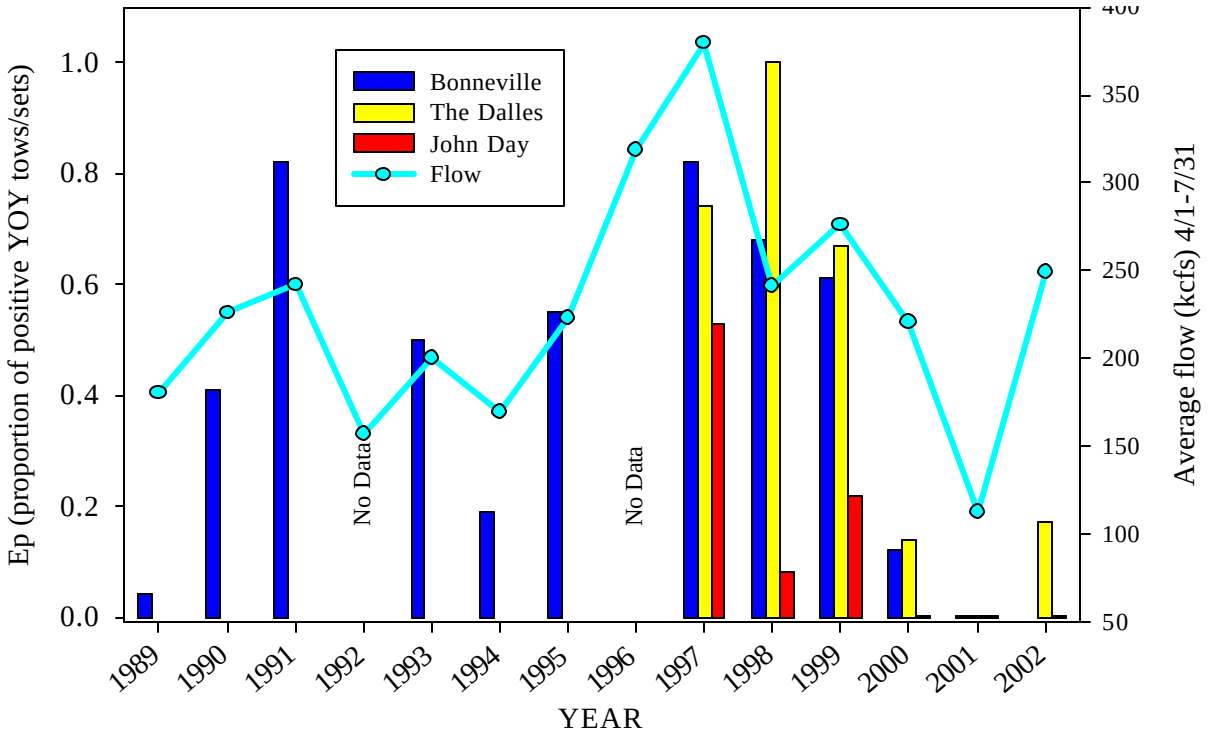
Pacific lamprey are a key indicator of the ecological health of the Columbia Basin and appear to be a choice food for avian and fish predators over salmon smolts (FCO 1959). Lamprey were designated as Category 2 candidate species for ESA listing in 1994 by the USFWS. The Council's 1994 Fish and Wildlife Program noted the decline of lamprey and requested a status report which was completed (Close et al. 1995). On January 28, 2003, Pacific lamprey were petitioned for ESA listing by a host of environmental organizations (ONRC 2003).

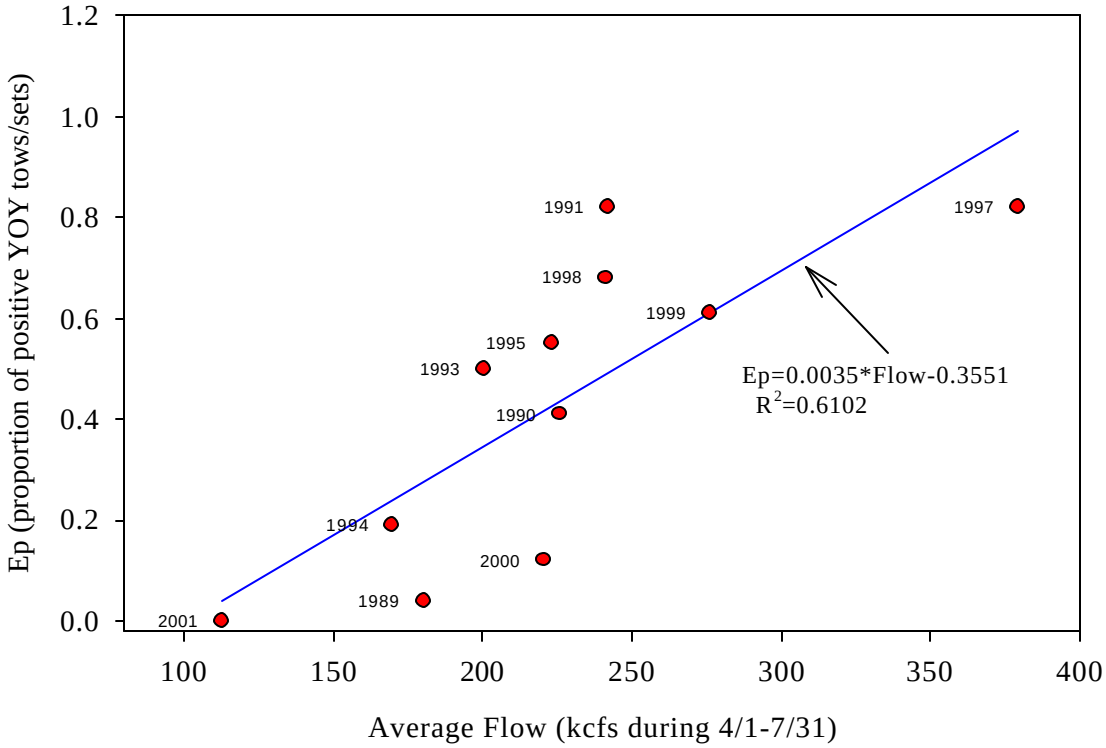
Pages 18. White Sturgeon

CRITFC recommends that the Council specifically include the following measures for white sturgeon in the Fish and Wildlife Program.

- Configure and operate the hydropower system consistent with salmonid recovery to maximize spawning and rearing success of white sturgeon in reservoirs.

Optimize spawning conditions by maintaining minimum discharge of 250 kcfs at McNary Dam during the time period when river temperatures are between 13 and 15 ^{o}C. Flow objectives of the NMFS Biological Opinion will meet discharge recommendations for optimal spawning conditions for white sturgeon. Potential yield of white sturgeon from impounded populations has been reduced by dam construction and operation of the hydropower system can have large effects on spawning habitat of white sturgeon. As can be seen in the following figure, during years of low discharge in spring and summer, the lack of high quality spawning habitat in impounded reaches may preclude successful reproduction. Recruitment to young of the year (less than one year old fish) is poor during these years of low discharge.





Supporting information can be found in the following journal articles:

Parsley, M. J., L.G. Beckman, and G.T. McCabe, Jr. 1993. 1993. Spawning and rearing habitat use by white sturgeons in the Columbia River downstream of McNary Dam. Transactions of the American Fisheries Society 122:217-227.

Parsley, M. J. and L. G. Beckman 1994. White sturgeon spawning and rearing habitat in the Lower Columbia River . North American Journal of Fisheries Management 14:812-827.

- Supplement depleted populations of white sturgeon in reservoirs until changes in configuration and operation of the hydropower system have resulted in restored populations.

Transplant naturally-produced juvenile white sturgeon from below Bonneville Dam into reservoirs. Transplant up to 10,000 juvenile white sturgeon annually from below Bonneville Dam to The Dalles and John Day reservoirs. Recruitment to white sturgeon populations in The Dalles and John Day reservoirs has been low since development of the hydropower system. Though development of the hydropower system has reduced availability of habitat for spawning white sturgeon in these reservoirs, it has increased the area suitable for young of the year and juvenile fish.

Supporting documentation can be found in:

Rien, T.A. and J. A. North. 2002. White sturgeon transplants within the Columbia River. Pages 223-236 *in* W.Van Winkle, P.J. Anders, D.H. Secor, and D. A. Dixon, editors. Biology, management, and protection of North American sturgeon. American Fisheries Society, Symposium 28, Bethesda, Maryland.

- Supplement populations with artificially-produced fish where risks to naturally spawning populations are minimal.

White sturgeon populations between Priest Rapids and Grand Coulee dams have little or no natural recruitment under the current hydropower system and there is little potential for providing flows that allow spawning and recruitment. Initiating hatchery release programs in areas of the Columbia and Snake rivers where production has been severely reduced or lost will allow establishment or re-establishment of white sturgeon fisheries.

Currently CRITFC staff are doing this work in a research program to determine the best strategies to conduct this option. Supporting documentation can be found in:

Ireland, S. C., P.J. Anders, and J. T. Siple. 2002. Conservation Aquaculture: An adaptive approach to prevent extinction of an Endangered white sturgeon population. Pages 211-222 *in* W.Van Winkle, P.J. Anders, D.H. Secor, and D. A. Dixon, editors. Biology, management, and protection of North American sturgeon. American Fisheries Society, Symposium 28, Bethesda, Maryland.

- Monitor status of white sturgeon populations to evaluate effectiveness of and ensure success of restoration efforts.

Monitor and regulate harvest of white sturgeon in reservoirs based on estimated abundance and exploitation rates that provide optimum sustainable yields. Reduced productivity of white sturgeon populations in reservoirs has complicated fishery management. Sustainable

harvest levels have been reduced by low productivity caused by poor recruitment and slow growth. Recruitment and growth have been reduced by altered flow regimes and degraded spawning and rearing habitat. Both limited fisheries and population recovery can be provided through intensive fisheries management.

Conduct periodic assessments of white sturgeon abundance, growth, recruitment, and age distribution in reservoirs. Periodic updates of population status will provide evidence of the success or failure of actions designed to restore white sturgeon populations. Information collected during assessments can be used to modify management approaches if necessary.

Without regular monitoring we cannot evaluate management and research recommendations. Currently the evaluation program has been on a 5 year rotation (i.e. sample each reservoir population every 5th year). Due to some substantial population changes, we have recommended in our most recently SOW of work that these evaluations be increased at the rate of every 3 years. This will allow a more rapid evaluation of specific management/research actions and enable these efforts to more effectively rebuild the populations. The following publication effectively captures all of the previously listed option for white sturgeon restoration under the Resident Fish heading.

Beamesderfer, R. C. P., and R.A. Farr. 1994. Alternatives for the protection and restoration of sturgeons and their habitat *in* Proceedings of the International Conference on Sturgeon Biodiversity and Conservation. New York City, New York.

Page 23 Juvenile and adult passage in general.

First bullet: Adult passage of salmon is of significant and equal importance to juvenile salmon migration. Significant loss of life history diversity is occurring due to impacts associated with the passage of juvenile salmon through the mainstem.

Third bullet: Salmon survival must not be sacrificed to the Corps' Value Engineering program. We recommend that this bullet be stricken from the draft unless the measure clearly identifies what aspects of Value Engineering the Council supports, why it supports them, and how Value Engineering will benefit salmon survival. In our experience, the Corps' desire to minimize the use of water to pass salmon through spill or bypass systems has been counter-productive to salmon survival.

Fourth bullet: The Council should not simply "assume away" the breaching of any mainstem dams. CRITFC's recommendations call for modification of the Snake River dams to natural river conditions. As identified in Attachment 3A to these comments, breaching the four lower Snake River dams should foreclose population extinction and allow for doubling of populations within 25 years. NMFS FCRPS biological opinion (RPA 147) calls for the development of a project management plan to reevaluate breaching the Snake River dams. The project management plan must

> "identify the scope, schedule, costs, tasks, products, and responsibilities for the reevaluation study. The study should assess all significant changed conditions to the Lower Snake River Feasibility Report and Environmental Impact Statement (Corps 1999c). The project management plan should be consistent with direction from Congress, Corps authorities, and other legal requirements. The completed project management plan should be coordinated with the appropriate regional interests. The project management plan should include, but not be limited to, plans to mitigate disproportionate impacts to communities, industries, and Tribes, detailed water and air quality effects, implementation plans, and a complete public involvement program." The decision to start the reevaluation study should result from the NMFS check-in process in Section 9.5. The Corps will request funding or reprogramming to complete the project management plan within 1 year after NMFS' issuance of a check-in report indicating the need to seek additional authority. The study should result in a general reevaluation report and supplemental environmental impact statement, which would be used to seek authorization and/or appropriations to implement, recommended action(s), if needed. The general reevaluation report/supplemental environmental impact statement will require approximately 2 years to complete."

From the preceding it is clear that the Corps must take actions to address the possibility of Snake River dam breaching during the period of the Council's intended mainstem amendments. Does the Council support RPA 147? Does the Council support the CRITFC recommendations regarding seasonal drawdown of Lower Granite Dam or restoring the natural channel of the Lower Snake River?

Page 24 Juvenile Fish Transportation.

The Program should be modified to allow spring and summer juvenile migrants in-river rearing and passage in an improved in-river mainstem habitat using the other recommendations provided by CRITFC.

General Concerns

Despite independent scientific review of transportation (ISAB 98-2) that included: 1) a management approach to alternate between barging and leaving fish in the river throughout the migration season (i.e. "spreading the risk"), 2) calling for cessation of truck transportation, 3) placing additional emphasis on alternatives to transportation and, 4) questioning whether juvenile transportation can be made compatible with all life histories and stocks (i.e. transportation selects against certain stocks and species), the Corps continues to specify barge and truck the majority of salmon from all stocks, listed and unlisted. Nor has the Corps conducted any studies comparing the relative survival of in-river migrants with adequate spill and flow augmentation to collected and transported migrants, including an examination of adult returns for these groups. Nonetheless, the Corps transports between 70-85% of the Snake juvenile migration (FPC 1999 and 2000) and up to 100% transportation of all Snake River summer migrants.

Bouwes et al. (2001) found in 4 out of the 6 years analyzed, transported wild fish actually exhibited slightly lower SARs (point estimates) than wild fish that migrated through the hydrosystem undetected. Sandford and Smith (2002) also demonstrated equivocal differences between transported (they did not evaluated total transport SAR from all projects) and control in-river migrants as only 4 out 20 data sets demonstrated significant benefits to an optimistic representation of transportation. See Joint Technical Memorandum to NWPPC, March 19, 2002. Our analysis also does not support the hypothesis that transportation provides a benefit to the overall survival of wild spring/summer chinook and steelhead. The spring/summer chinook and steelhead SARs were not significantly influenced by the transportation proportion, and the spring/summer chinook SARs actually decreased as the proportion of smolts transported increased.

Transportation has failed to demonstrate statistically significant increases over fish that migrate in-river. By applying similar logic used to reject flow target as a management tool, we would expect the Council to adopt a management action that ceased transportation as well. CRITFC opposes the high priority given to the proposed new fish transport studies. Both CRI and PATH analyses have shown that it is very unlikely that improvements in transportation survival will be adequate to meet NMFS's survival and recovery standards. While CRITFC and its member tribes do not support any transportation, should transportation studies be implemented we urge that the recommendations of the ISAB (1998) and ISAB (2002-1) be followed to require the Corps, BPA, and Bureau of Reclamation to provide good in-river conditions (spill and flow augmentation) to allow transportation and in-river migration to be meaningfully compared. Any analyses should include comparisons of smolt-to-adult survivals back to the spawning grounds and should avoid bias in methods such as marking in-river fish after they have experienced dam bypass systems. These remain serious critical uncertainties that demand resolution. The conduct of these studies and experimental designs should be closely coordinated with the state and tribal fish managers and be subjected to review by an independent, scientific party.

Truck transportation

The Council should support abandoning truck transportation of juvenile salmon. Because no studies have been accomplished examining the differential survival of truck transported subyearling chinook and those allowed in-river passage via spill, there is great uncertainty with respect with truck transportation of these salmon, especially from the Lower Snake dams that are hundreds of miles from saltwater. In their comprehensive review of transportation, the Independent Scientific Advisory Board (ISAB) noted, "uncertainties associated with potential negative effects of transportation on genetic and life history diversity." (ISAB 1998).

Further, the ISAB noted that juvenile fall chinook should not be truck-transported, "because historical indications on truck transport are negative." (ISAB 1998). Further, it recommended that because of the uncertainties of transportation, trucking should not be the sole management regime for an entire stock (ISAB 1998). Trapping rearing juvenile fall chinook,

starving them in the screen systems and trucks, and releasing them into the estuary before they are physiologically adapted to saltwater, may likely result in lower smolt-to-adult returns.

Reimers (1973) and Williams et al. (1996) note the importance of a rearing life history for subyearling fall chinook suggesting that this parameter is very important for survival and overall stock production. Lichatowich and Cramer (1979) found that the low coefficient of variation (high sensitivity) for measurements of time and size of the peak of the juvenile migration, facilitated by in-river migration into saltwater, suggested that this parameter is very important to stock survival and overall production.

In an independent assessment of transportation, Mundy et al. (1994) noted that the extended rearing life histories necessary to Snake River fall chinook made the practice of collection and transportation from Snake River dams a highly uncertain management practice. The Plan's recommendations acknowledge the fact that fall chinook production is sensitive to the proper time and size of juvenile migrants as they enter saltwater, which is best realized by in-river migration (Lichatowich and Cramer 1979; Reimers 1973).

Migrants should be left in the river to complete their freshwater life histories including reaching optimum size and timing into salt-water. Additional flows and spills in September should be provided to protect adult migrants from powerhouse passage and assist in minimizing energy expenditures to allow for successful spawning. These parameters have been found to be highly influential in promoting overall stock production (Lichatowich and Cramer 1979; Reimers 1973, Williams et al. 1996).

Recent Transportation Results

When delayed mortality impacts are considered, juvenile salmon bypass into turbine intake screen systems and transportation in all but the lowest flow years appears equivocal at best or detrimental at worst. Budy et al (2002) noted that direct mortality of 25-73% takes place while Snake River juvenile and adult salmon bypass dams and travel through reservoirs and or are transported by barge and truck. An additional 37-68% indirect or delayed mortality occurs on top of the direct mortality. The delayed mortality occurs as a result of transportation stress, loss of energy reserves, compromised behavior which exposes smolts to disease and predation and loss of physiological adaptation, such as premature placement of smolts in saltwater.

Recent data from NMFS' transportation studies[3] indicates that more wild spring and summer chinook adults returned from 2000 releases at Lower Granite Dam from in-river groups that were not detected as passing through screened bypass systems than transported groups (157 in-river v. 122 transported; Marsh et al. 2002). As of the November, 2002, NMFS reported only 20 wild spring and summer chinook adult returns to Lower Granite from the 2001 drought year releases. There were no in-river releases that year because all fish diverted into screen systems

[3] NMFS study protocols involve marking in-river and transportation groups after both have passed through and have suffered impacts and bias from screened bypass systems. The CBFWA Comparative Survival Study (Bowles et al. 1999) avoids this bias by marking fish upstream of hydroprojects and screened bypass systems. Despite the bias introduced by NMFS' study protocols, in-river groups have on several occasions returned more adults than transported groups.

were transported, but Comparative Survival Study results should be available in the near future. Preliminary results for subyearling fall chinook transported in 2001 using NMFS study protocols (marking both in-river and transport groups at McNary Dam) indicate transportation is a detriment (20 in-river to 13 transported).

The ISAB (2002) concluded that for steelhead, it is difficult to conclude which is better-transportation or in-river passage through the Snake River. Similarly, the ISAB concluded that, *"[N]o clear benefit has been shown for transportation of smolts of spring/summer chinook and steelhead stocks from Lower Monumental or McNary dams."* The ISAB supports reevaluation of these sites for transportation. Further, the ISAB stated it was advisable to discontinue transportation in the early spring due to poor results. The ISAB also criticized the use of transport to in-river ratios that are the foundation of NMFS transport studies, because, "[t]hey have poor precision that their usefulness may be questioned." Finally, the ISAB noted that homing of adult salmon is likely to be impacted by transportation and that the transportation process, due the screen bypass operation, may select against certain life histories and stocks and that this is not, "[d]esirable for long-term sustainability." In years with normal or high flows the ISAB suggest that it would be better to minimize transportation to reduce this selective pressure. They state that the data is weak and available studies have different designs, but just because a statistical difference cannot be detected, does not mean that there is no effect from selective pressures.

Page 25 Spill

Spill has been shown to offer the best protection for juvenile migrants and to speed their migrations through the hydrosystem corridor (CRITFC et al. 1994; STFA 1995) and is consistent with the normative river approach (Williams et al. 1996). For example, without spill, the low guidance efficiencies for subyearling fall chinook at the Lower Snake dams force about 50% of migrants to turbine passage. NMFS pit-tag studies indicate that very few, if any, of the migrants that are subjected to turbine passage survive through the Snake River (Smith et al 1997).

CRITFC notes that the Independent Scientific Advisory Board's recent evaluation of gas abatement (ISAB 98-8 Review of the U.S. Army Corps of Engineers Dissolved Gas Abatement Program) and the NMFS' draft 2000 Biological Opinion for the Federal Columbia River Power System (NMFS 2000) found that dissolved gas levels of 120% saturation were conservative and not harmful to salmon in the river. Further, analysis of three years of research from in-river juvenile salmon sampling in the Columbia River indicates that very low incidences of GBT were found in juvenile salmon that were exposed to dissolved gas levels up to 125% saturation (Backman et al. 2000). Specifically, Backman et al. (2001 in press) found no statistically significant relation between total dissolved gas and gas bubble trauma for chinook salmon. Most gas bubble trauma symptoms were minor (>5% fin occlusion) with severe bubbles (>26% fin occlusion) being observed only when total dissolved gas exceeded 126%. Chinook salmon were rarely observed with gas bubble trauma, despite sampling large numbers when total dissolved gas exceeded 130% saturation (Backman et al. 2001 in press).

With respect to indirect and delayed mortality estimates to juvenile salmon from the different passage routes at Bonneville Dam, CRITFC offers the research findings by NMFS

(Gilbreath et al. 1993). In the only relative survival study conducted at Bonneville Dam for juvenile fall chinook that passed concurrently through turbines, screened bypasses and spill, mortality rates were about 18%, 20% and 4% respectively. These estimates were from juveniles recovered in the Columbia River estuary and were statistically significant at the 0.05 alpha level.

Further, recent juvenile survival data indicates that juvenile survival is increased with higher spill levels, even if these levels cause total dissolved gas in the river to exceed 125% total gas pressure. Analysis offered by the Fish Passage Center indicates that juvenile chinook survival in spring of 1994 with a 10.5% spill level at Lower Snake dams was 0.698; the survival of juvenile chinook in spring 1996 though the same Lower Snake dams at a 24.7 % spill level was 0.857 (DeHart 1999).

Spawner-to-spawner analyses also indicate that smolt-to-adult survival rates are higher years with high flows and high spill, even though the spill created elevated total dissolved gas levels that were exceeded 125% total gas pressure (Petrosky and Schaller 1998; Deriso et al. 1996; Schaller et al. 1999). Thus, CRITFC believes that spill would result in greater juvenile survival and overall stock productivity because indirect and delayed mortality is less for spill than for turbine or screen system passage.

Many adult steelhead kelts will be migrating downstream through the hydrosystem in March through May. Radio telemetry studies indicate that between 35-50% of steelhead in the Columbia Basin are repeat spawners and return to the ocean (English et al. 2001; Evans and Beaty 2000). Spill will significantly increase the survival of these salmon as well as adult chinook and steelhead that fallback through the dams as they immigrate upstream to spawning areas. Estimates of adults that fallback through the juvenile screen system at McNary Dam alone range from 9,000-10,000 adults in a single year (WDFW 1998-2000). About 31% of adult steelhead that fell back through the McNary Dam juvenile screen systems were found to suffer 39.2% physical injuries (Wagner and Hilson 1991). As mentioned above, adults that pass through dam powerhouses suffer significant mortality rates.

CRITFC recommends passing 90% of juvenile migrants over 100% of the migration through dams via spillways and sluiceways and other surface bypass systems. Ideally, controlled spill should be implemented for 24 hours a day, 7 days a week to the dissolved gas variance. General planning dates for spill should be March 20-September 30. Actual timing of spill should be determined by sampling at dams and in the river. Spills at this level should continue until 95% of the fall chinook migration has passed each individual dam as indicated by screen bypass indices, and hydroacoustic technology, and in-river sampling. The spill period should be April 1- September 15 for Lower Granite through McNary and March 21 through October 1 at John Day, The Dalles and Bonneville. During spring and summer fish migrations, we recommend spill for each dam based upon spill variances for total dissolved gas. Spill levels are expressed in total volume or percent of flow in spill (daily average flow or daf).

Project operators should obtain flexibility for spill from the appropriate tribe and/or state water quality agencies in a manner to allow spill to be applied each year. Further, the Council should allow the use of spill to meet passage standards of 90% fish passage efficiency through spill and surface bypass passage. The Council should adopt spill up to 125% total gas pressure

in the tailraces of each dam, as this level has been demonstrated to provide higher salmon survival levels than other routes of passage and little risk to adult and juvenile salmon in the river due to depth compensation (NMFS 2000); Agencies and Tribes Risk Assessment ; Backman et al 2002; Backman et al. in press). The Program should require that spill levels are hard constraints, not be abridged or violated for the sake of research or transmission deficiencies or financial emergencies without the full consensus of the tribes and fishery agencies.

Project-by-Project Spill Requirements

Project operators should meet the following recommended spill levels. These levels should be adjusted upwards to conform to the increase in spill variances to 120-125% TGP:

Project	Spring Spill Levels	Summer Spill Levels
BON		
Day	75kcfs vs.120-150 kcfs	75 vs. 120-150 kcfs
Night	120-150 kcfs (Cap)	120-150 kcfs (Cap)
TDA		
Day	50% of flow	50% of flow
Night	50% of flow	50% of flow
JDA		
Day	30%	30% Vs 60%
Night	45%	60%
MCN		
Day	50%	50%
Night	50%	50%
IHR		
Day	45 kcfs	45 kcfs
Night	65 kcfs vs. 100 kfcs	65 kcfs vs. 100 kfcs
LMN		
Day	40 kcfs	30 kcfs
Night	40 kcfs	40 kcfs
LGS		
Day	45 kcfs	30 kcfs
Night	45 kcfs	45 kcfs
LGR		
Day	22 kcfs vs. 60 kcfs	22 kcfs vs. 60 kcfs
Night	60 kcfs (Gas Cap)	60 kcfs (Gas Cap)

Page 28 Juvenile Fish Bypass Systems.

We support juvenile fish passage strategies and actions to maximize project survival through spill and surface bypass. We do not support collection, and powerhouse intake screen and bypass systems for these selected against stocks and life histories (NWPPC 1999). These screen systems also incur 2-3 times greater direct mortality than spill and there is evidence that they are responsible for significantly greater delayed mortality to juvenile salmon than spill (see CRITFC SIMPAS modeling assumptions and CRITFC comments to NMFS 1999 Passage white paper). The Council should require that reach and project-specific relative survival studies be conducted so as to compare mortality of juvenile and adult salmon passing through powerhouses with and without screen systems and with spill and surface bypass systems. Radio-telemetry methodologies should be prioritized because to be valid, PIT-Tag survival studies require underlying assumptions that cannot be met in the field. For example, the Anderson-Burnham model, the foundation of these studies, requires that treatment and "control" groups experience identical downstream environmental conditions (Burnham et al. 1987). Chi-Square goodness of fit tests between these groups often indicate that this assumption cannot be met, because groups are not detected at the same time at downstream dam detection points (Skalski 2000 pers. com.).

We urge the Council to support testing of a full flow bypass (without dewatering) to reduce stress and mortality of juveniles that occur from dewatering, holding, and handling. CRITFC recommends that the priority for this system to be tested, implemented and evaluated should be at the Bonneville 2 powerhouse. Evidence from PIT tag studies (NMFS Section 7 Consultation Passage White Papers) strongly suggests that mortality is increased for fish bypassed through screen systems at multiple projects. This mortality may be reduced by use of high flow bypass systems that move fish quickly through forebays and safely to tailwater without subjecting fish to the effects of dewatering, delay and handling in juvenile fish facilities.

The Program should be modified to require that turbine intake screens be removed from all dams until comparative research, using smolt-to-adult returns, conclusively indicates that screen bypassed salmon, barge transported salmon and Pacific Lamprey are better served passing through screen systems than index-tested turbines operated within the 1% peak efficiency range.

Evidence is mounting that screen systems may cause more juvenile mortality than turbine passage. Screen systems may also select against stocks such as sockeye and lamprey and life histories such as fry and subyearling chinook (Gilbreath et al. 1993; ISAB 98-4; ISAB 1999; IDFG 1997). The NMFS and the Corps are still proceeding with installation of screen systems at federal dams in the Columbia and Snake Rivers. The Corps has failed to conduct the required evaluations for impacts of turbine intake screens on subyearling spring, summer and fall Chinook, including fry. In 1997 alone, an estimated 356,651 juveniles died at screen systems in the basin (WDFW, NMFS, ODFW 1997 Reports). Some of these mortalities were spring and summer chinook. Descaling by screens is a serious problem. NMFS biologists reported that 27% of descaled juvenile steelhead died at Bonneville Dam when held for 48 hours (CRITFC 1997b). Analyses by IDFG (1997) indicate that multiple passage through screen systems are correlated with the reduction of spring and summer chinook smolt-to-adult survivals.

Evidence exists indicating that juvenile salmon injured and stressed from contact, hydraulics, and dewatering from screened bypass systems, and then concentrated at outfall release sites in dam tailraces, suffer significant predation from pikeminnows and avian predation.

Piscivorous predators can temporarily hold in high velocity areas near outfall sites and can succesfully engage in predation (Chapman and Witty 1993). Poe et al (1994) noted that predation downstream of screen system outfall pipes highly influences the survival of smolts that pass dams through screen systems. Studies indicate that most predation occurs in dam forebays and tailraces (Chapman and Witty 1993). Venditti et al. (1997) noted that slackwater in dam powerhouse forebays was likely responsible for radio-tagged Snake River fall chinook to reverse migration and swim a significant distance (14.4 km) upstream. Avian predators have been observed to be successful in preying on smolts concentrated at screen system outfalls (Jones et al. 1996).

Fish guidance efficiency (FGE) of screen systems is variable during the migration season. FGEs are typically low during the early part of the spring migration, then reach their highest level during the middle of the spring migration, then drop during the middle to the end of the summer migration (CRITFC 1997). Because the majority of FGE tests are during the middle of the spring and early summer migrations, FGE rates are inflated and not truly representative of the screen systems to divert salmon from turbine intakes.

Turbine Passage

The Program should require project operators to maintain turbine operations at all dams within the 1% peak efficiency band from March 20-November 1 at the Lower Snake dams and from March 20- December 1 at the Lower Columbia dams. Furthermore, operators should remove turbine intake screens as needed to maintain the peak efficiency band. Screens, especially extended length screens, perturb hydraulic flow lines into turbine intakes and reduce turbine efficiency (Wittenger, 1998 pers. comm). Smolts that are not guided by screens are forced through turbines at lowered efficiency; likely causing increased mortality rates (Bell 1991). Each turbine unit should be hydraulically assessed (index-tested) and rated with an individual peak efficiency band – minimum servo-stroke to blade gate angle (not limited to "families of turbines as is now the case") to optimize performance (Shelton 1982). Each turbine should be hydraulically assessed for structural repairs or modifications that will improve its individual efficiency to optimize performance. Turbine operations should be monitored via individual powerhouse automated monitoring systems on a real-time basis during the anadromous fish migrations to insure compliance with optimum performance to reduce and adult mortality. Reservoir tailwater fluctuations that can cause cavitation and poor turbine unit performance that increase salmon passage mortality should be significantly reduced.

Page 28 Adult Passage.

The Council should adopt measures requiring spill for adult migrants. After 98% of the juvenile migration has passed a dam, the Program should specify that spill is continued but modified for adult passage. The end spillbays next to the adult ladders should be opened to spill 1-3 kcfs each for adult attraction to the ladder entrances. Further, endbay spill and continued sluiceway and/or surface bypass operation provides a vital downstream passage route for many adult fall chinook and steelhead that fall back over dams. This operation should begin about March 15 to protect steelhead kelt migrations downstream and continue until November 1 at the

Lower Snake dams and until December 1 at the Lower Columbia dams, and has been recommended in the past by FPAC (1994) and the fishery managers (DFOP 1993).

Biological Rationale: The direct take of listed and unlisted fall chinook and listed steelhead that fall back through screens system and turbines has not been addressed by the federal government (CRITFC 1999). At McNary Dam alone, 7,000-11,000 steelhead were documented to fallback through the screen bypass system (Wagner and Hilson 1991). Wagner and Hilson (1993) noted that over 7,000 steelhead fell back through the McNary Dam powerhouse. Of adults observed in the screened bypass system, they noted that 39% of them had visible bruises. NMFS (1995) noted a direct kill of 41% of adult salmon that passed through a Kaplan turbine. Evans and Beaty (2000) noted that about 30% of spring steelhead fallbacks were kelts heading to sea. Loss of adult migrants through powerhouse fallback selects against population abundance and genetic diversity.

Further, the Council should adopt measures that require the Corps and the Mid-Columbia PUDs, in consultation with the tribes and state and federal managers, to 1) evaluate problem passage areas for adults thorough dams and 2) provide specific structural and operational remedies to correct these problem areas. The Council should encourage the hydroperators to concentrate on reductions of long passage timing and not median passage timing. The Council should adopt measures for the hydro operators to reduce temperatures in adult fishways and to establish comprehensive water quality monitoring systems in all fishways.

Pages 29 to 38 Water Management.

The Program should require that runoff and storage volumes be managed to more closely approximate the natural, historic river hydrograph (Williams et al. 1996; CRITFC 2000b). A normative river hydrograph promotes physical, chemical and biological parameters necessary for anadromous fish production. For example, turbidity regimes established by a peaking hydrograph have been shown to enhance anadromous fish production in the mainstem (Junge and Oakley 1966) and estuary (Bottom and Jones 1990; Maser et al. 1988). A peaking hydrograph also transports large woody debris and inorganic and organic sediment creating habitat diversity and a base for primary and secondary invertebrate production (Lisle 1986; McMahon and Holby 1992; Johnson et al. 1995). Biodiversity is best protected in rivers with natural flow regimes (Power et al. 1996).

The Program should require that the Corps, BPA, Reclamation and the Mid-Columbia PUDs, through hourly coordination of their projects, develop an operation and provide funding for studies that reduce flow fluctuations in the Hanford Reach that strand juvenile salmon and limit spawning habitat for bright fall chinook.

The normative river hydrograph includes meeting flow objectives at each of the main river points- Lower Granite, Priest Rapids and The Dalles,[4] while retaining water in storage

[4] The Dalles is appropriately the index point because it has been *the* lower Columbia point where flows have been measured since the 1878. The use of McNary Dam as a downstream index point is not appropriate because storage and power operations in the John Day pool perturb flows below John Day. These perturbations are counter to a

reservoirs to meet integrated rule curves and other biological criteria. The concept relies on flexibility in flood control, flow augmentation from Non-Treaty storage and purchase of flood control space, and appropriate contributions from irrigation withdrawals.

The following table describes the flow recommendations of CRITFC. We recommend that these flow measures substitute for those contained in the Council's draft Amendment Document.

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natural flow regime in the lower Columbia and estuary and are not evident if McNary is used as the lower river index point.

Hydro-system operations to meet flow objectives in the Columbia and Snake Rivers.						
Biological Opinion Action No.	*Purpose of Action*	**Project(s)**	**Biological Opinion Operation**	*Modified Operation*	*Benefit*	*Risks*
18	Create a more natural flow regime on the lower Columbia and lower Snake Rivers.	Grand Coulee Dworshak Brownlee Hungry Horse Libby Arrow (BC) Mica (BC)	Operate to meet April 10 flood control elevations; operate to meet spring flow objectives; refill by June 30.	**Operate Grand Coulee, Dworshak, Brownlee, Hungry Horse, and Libby, plus Arrow and Mica, to achieve a natural peaking flow regime during spring and summer. Modified Upper Rule Curves plus a May 31 refill date are used to achieve Altered Flood Control operation.**	**A more natural flow regime coincides with salmon life cycle and survival. Specifics: increased river turbidity, higher passage velocity, cooler water, more habitat, larger estuary plume, and higher chance of reservoir refill. Plan takes advantage of global warming by moving to earlier refill.**	**Flood control protection is comparable with Federal operation. Minor nuisance flooding in the lower Columbia is possible under the highest of water years. Total Dissolved Gas levels may temporarily rise during the passage of controlled flood pulses.**
19	Create a more natural flow regime in the lower Columbia River while providing protection for bull trout.	Hungry Horse	By January 1, 2001, implement VARQ flood control; provide minimum flows for bull trout and at Columbia Falls; limit summer draft to elevation 3540 ft by August 31.	**Implement modified VARQ for Hungry Horse…creating a spring/summer natural flow regime with a smooth recession. Provide water for Columbia Falls minimum flows. Use sliding scale for minimum flows (400 – 900 cfs), based on April-September Water Supply Forecast for HGH Inflow.**	**Help create natural flow regime in the lower Columbia while balancing the needs of resident fish. This action increases survival of spring and summer juvenile salmon migrating through the federal hydro system. Less spring flood risk.**	**Water elevations in Hungry Horse may be 0.5 to 1 foot lower in the July and early August, and 2 to 3 feet lower in winter, compared to the Biological Opinion. This action may impact certain recreational opportunities in the reservoir and may reduce the amount of water available for meeting winter power needs.**

Hydro-system operations to meet flow objectives in the Columbia and Snake Rivers.						
Biological Opinion Action No.	*Purpose of Action*	**Project(s)**	**Biological Opinion Operation**	*Modified Operation*	*Benefit*	*Risks*
19	Create a more natural flow regime in the lower Columbia River while providing protection for bull trout.	Libby	By October 1, 2001, implement VARQ flood control; provide minimum flows for bull trout; limit summer draft to elevation 2439 by August 31.	**Implement modified VARQ for Libby…creating a spring/summer natural flow regime with a smooth recession. Modify December preemptive draft from 2 MaF (2411 feet) to 1.5 MaF (2424 feet).**	**Help create natural flow regime in the lower Columbia while balancing the needs of resident fish. Provide more flow in low years. This action increases survival of spring and summer juvenile salmon migrating through the federal hydro system.**	**Water elevations in Libby are 5 feet higher throughout the year, on average, compared with the Biological Opinion.**
19	Determine if operation improves spawning success for kokanee, an important bull trout forage fish.	Albeni Falls	Draft to elevation 2051 ft by August 31; refill to and maintain elevation 2055 ft during fall/winter for kokanee spawning study. Beginning in 2004, implement operation recommended by USFWS and NMFS.	**Refill to and maintain elevation 2055 ft at Albeni Falls during the fall/winter only when water supply is sufficient to ensure the operation does not reduce probabilities of meeting salmon spawning flow objectives.**	**Increased probability of meeting fall spawning flow objectives. This action increases production of chum and chinook salmon downstream from Bonneville Dam.**	**Under low runoff conditions, water elevations in Albeni Falls may be lower in fall and winter. This may or may not provide ideal conditions for kokanee spawning and forage for bull trout.**
19	Create a more natural flow regime in the lower Columbia River while providing protection for kokanee.	Grand Coulee	Operate to achieve 85% probability of meeting April 10 rule curve and refill by July 4 if a draft is not required to meet flow objectives; limit August 31 draft to elevation 1280 ft when runoff forecast = or >92 Maf and to elevation 1278 ft when forecast <92 Maf.	**Implement Altered Flood Control Rule Curve. URC fills on May 31. In low years, draft to 1287 feet by April 15, 1275 feet by April 30, and 1260 feet by May 31 to enhance Hanford Reach flows. In high and medium years, draft 1 foot in July (1289 ft) and 6 feet in August (1283 ft), then hold pool through November. In low years, draft 10 feet in July, hold through August, fill to 1283 feet by September.**	**Help create natural flow regime in the lower Columbia while balancing the needs of resident fish. This action increases survival of summer juvenile salmon migrating through the federal hydro system. Reduce winter wind erosion of the Lake Roosevelt shoreline. Maintain steady pool during autumn treaty fishery in the lower Columbia.**	**Water elevations in Lake Roosevelt may be near full in December and January. During low years, water elevations in May are 23 feet lower than Biological Opinion operations and may impact certain recreational opportunities and other uses in the reservoir.**

Hydro-system operations to meet flow objectives in the Columbia and Snake Rivers.						
Biological Opinion Action No.	*Purpose of Action*	**Project(s)**	**Biological Opinion Operation**	*Modified Operation*	*Benefit*	*Risks*
19	Create a more natural flow regime in the lower Snake and Columbia Rivers and strive to meet EPA's 68F temperature criteria.	Dworshak	Attempt to refill by June 30 while coordinating with TMT to meet spring flow objectives; limit draft to elevation 1520 ft by August 31; manage discharge to achieve 68F at Lower Granite.	**Implement Altered Flood Control Rule Curve. Fill on May 31 whenever possible. Implement Nez Perce Tribe-Idaho Summer Plan: full pool through July. Draft 1 MaF (to 1537 feet) by August 31, then 200 KaF (to 1520 feet) by September 30. In low years, draft 10 feet during July (to enhance water quality) and dovetail into the NPT plan during August.**	**Help create natural flow regime in the lower Snake and lower Columbia while balancing the needs of juvenile and adult salmon. This action increases survival of summer migrating juvenile salmonids through the federal hydropower system.**	**April outflows from Dworshak may approach the TDG standard. Clearwater and lower Snake River waters may heat up by late July.**
19	Create a more natural flow regime in the lower Snake and Columbia Rivers.	Brownlee		**Implement Altered Flood Control Rule Curve. Fill on May 31 whenever possible. Draft 300 KaF during July and 150 KaF during August. Refill during September. Sliding scale (9000 – 13000 cfs) Fall Chinook spawning flows based on January 1st LWG water supply forecast (January-July period).**	**Help create natural flow regime in the lower Snake and lower Columbia. This action increases survival of summer migrating juvenile salmonids through the federal hydropower system. Reduce thermal impacts during mid-late summer.**	**Lower July elevations in Brownlee reservoir may impact certain recreational opportunities.**
19	Improve summer flows by 1000 KaF in the lower Snake and Columbia.	Upper Snake		**Obtain 1000 KaF from willing irrigation sellers via Idaho's Water Bank. Modeled values come from BOR 1-MaF study. The 1000 KaF amount is on top of the current 427 KaF flow augmentation program.**	**Help create natural flow regime in the lower Snake and lower Columbia. This action increases survival of summer migrating juvenile salmonids through the federal hydropower system.**	**Water may not be physically available in all water years. Number of sellers can vary each year.**

Hydro-system operations to meet flow objectives in the Columbia and Snake Rivers.						
Biological Opinion Action No.	*Purpose of Action*	**Project(s)**	**Biological Opinion Operation**	*Modified Operation*	*Benefit*	*Risks*
19	Create a more natural flow regime in the lower Columbia River.	Mica and Arrow, BC		**Implement Altered Flood Control Rule Curve. Fill on May 31 whenever possible. Conduct spring draft during low water years to assist Grand Coulee and Hanford Reach operations.**	**Help create natural flow regime in the lower Columbia while balancing the needs of upriver resident fish. This action increases survival of summer juvenile salmon migrating through the federal hydropower system. Reduce winter wind erosion of the Arrow Lakes and Lake Kinbasket shorelines.**	**Water elevations in Arrow Lakes may be lower in November and December but higher in January through March. This action may impact certain recreational and other opportunities in the reservoirs.**
20	Increase water velocity to provide faster juvenile emigration and improve survival.	Snake River Projects John Day	Operate Snake River projects within 1 ft of MOP April 3 until small number of juveniles are present and John Day within 1.5 ft of MIP April 10-September 30.		**Reductions in travel time and corresponding increase in survival of spring and summer migrating juvenile salmonids through the federal hydropower system.**	
23	Improve summer flows by 250 KaF in the lower Columbia.	Banks Lake	Operate Banks Lake at 5 ft from full during August by reducing 130 Kaf water pumped from Lake Roosevelt.	**Divert flows back into Lake Roosevelt, as follows. July, 4500 cfs; August 1-15, 4000 cfs, August 16-31, 2350 cfs, and September, 500 cfs.**	**Increased probability of meeting Columbia River summer flow objectives. This action increases survival of summer migrating juvenile salmonids through the federal hydropower system.**	**Water may not be physically available in all water years.**

Hydro-system operations to meet flow objectives in the Columbia and Snake Rivers.						
Biological Opinion Action No.	*Purpose of Action*	**Project(s)**	**Biological Opinion Operation**	*Modified Operation*	*Benefit*	*Risks*
24	Meet summer flow objective at McNary Dam.	Canada Treaty storage	BPA and Corps negotiate agreements to provide 1 maf Treaty storage January-April 15 for release during summer.		**Increased probability of meeting Columbia River summer flow objectives. This action increases survival of summer migrating juvenile salmonids through the federal hydropower system.**	
25	Improve summer flows by 1000 KaF in the lower Columbia.	Canada non-Treaty storage	BPA and Corps request from BC Hydro storage of non-Treaty water during spring for release in July and August if forecasts indicate that stored water can be released.	**The 1000 KaF is evenly divided across July and August. Refill occurs during October through February.**	**Increased probability of meeting Columbia River summer flow objectives. This action increases survival of summer migrating juvenile salmonids through the federal hydropower system.**	

Mainstem Water Withdrawals

Water withdrawals from the Columbia and Snake rivers significantly reduce flows necessary for anadromous fish and create additional pressure on upriver reservoir storage for resident fish. A 1999 study by the Bureau of Reclamation indicated that the Washington Department of Ecology has issued over 200,000 cfs of irrigation water rights, nearly 8 million acre feet per year during the April-November irrigation season above McNary Dam. On the Snake River about 4 million acre feet have been granted to irrigation above Lower Granite Dam. These water withdrawals account for almost 40% of the average natural river flow at McNary during low flow periods. The Washington Department of Ecology has issued 150 additional water withdrawal permits amounting to some 1600 cfs when they are fully utilized. Biological Opinion target flows cannot be met, in part, because of these significant withdrawals.

A recent decision by the Washington Department of Ecology to withdraw the moratorium on mainstem withdrawals has opened the door for many new applications for water right permits. Ecology has also instituted a review of water rights and flow needs for fish by retaining the National Research Council.

The Council should adopt measures that recommend the cessation of any more withdrawals from the mainstem river for any purpose until the scientific issues of anadromous and resident water needs are fully analyzed from a basin wide (including Canada) perspective. Tribal water rights must be given the highest priority in these considerations.

Flow, Survival and Productivity

There is a strong relationship between flows and salmon productivity, as noted by the "State, Federal, and Tribal Anadromous Fish Managers Comments on the Northwest Power Planning Council Draft Mainstem Amendments as they Relate to Flow/Survival Relationships for Salmon and Steelhead. January 2003 (Attachment 5). NMFS in its appendix to the 1995-1998 FCRPS Biological Opinion entitled *Basis for Flow Objectives for Operation of the Federal Columbia River Power System* also provides an excellent discussion of flow needs.

Higher flows and attendant spill have been demonstrated to reduce juvenile mortality and increase smolt-to-adult returns (Petrosky 1991; Petrosky 1992; Petrosky and Schaller 1998). Flows and spill enable juvenile salmon to arrive at the estuary at proper size and physiological condition to survive at sea (CBFWA 1991). Lichatowich and Cramer (1979) found that the proper size and time of juvenile arrival to the estuary is a statistically sensitive parameter highly influencing stock productivity. Healy (*in:* Groot and Margolis 1999), Hilborn et al. (1993) and Cada et al. (1994) also found that there is a strong, positive relationship between river discharge and the survival of juvenile salmon and the size of salmon spawning populations. Northcote and Larkin (1989) note that flows increase the quantity and quality of river and estuarine habitat diversity, which provides habitat conducive to rapid juvenile growth and subsequent high survival at sea.

Williams et al. (1996) and Dodge et al. (1989) note that anadromous fish production in the Columbia Basin and in rivers worldwide were founded and sustained upon the spatial and temporal cues and trophic systems created by the physical and chemical environment characterized by a normative hydrograph. Cada et al. (1994). These studies provide evidence of the linkage between flow, habitat accessibility and survival.

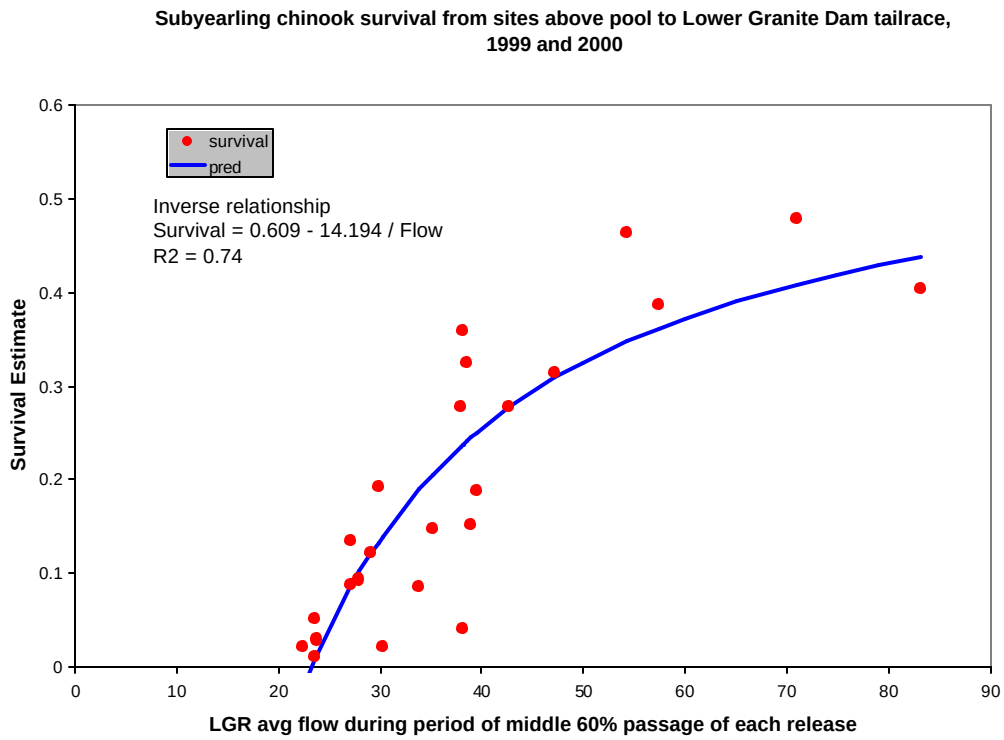
The following tables and attached graph, developed by the Fish Passage Center, illustrate a significant flow/survival relationship for these groups of summer migrants. Subyearling fall chinook PIT tagged at Lyons Ferry Hatchery and trucked and released at various sites in the Snake River from early June through early July show substantially lower survival estimates to Lower Granite Dam when average flows during the period of middle 60% passage at Lower Granite Dam drops below 50 kcfs. Flows in 2000 during the summer were lower than in 1999, and estimated survival to Lower Granite Dam remained lower for each weekly release group. The results here reflect the year-to-year difference for that fall chinook that outmigrated as subyearlings.

	Year 1999 Pittsburg Landing AP (KM 346)			**Year 2000 Pittsburg Landing AP (KM 346)**		
Release date	**Survival to LGR**	**Mid-60% Passage**	**Avg. Flow (kcfs)**	**Survival to LGR**	**Mid-60% Passage**	**Avg. Flow (kcfs)**
June 1	0.479	6/20-8/2	71.0	0.152	6/25-7/4	39.0
June 8	0.463	6/28-8/11	54.3	0.040	7/1-7/30	38.1
June 15	0.277	7/24-8/19	42.7	0.086	7/9-8/17	33.8
June 22	0.325	7/28-8/31	38.6	0.022	7/17-8/26	30.2
June 29	0.122	8/7-9/27	29.1	0.029	8/7-9/7	23.8
July 6	0.088	8/11-10/13	27.2	0.010	8/7-9/17*	23.6

* For July 6, 2000, release assume 80% date 10 days later than that of June 29 release.

	Year 1999 Asotin (KM 234)			**Year 2000 Above Captain John Rapid AP (KM 266)**		
Release date	**Survival to LGR**	**Mid-60% Passage**	**Avg. Flow (kcfs)**	**Survival to LGR**	**Mid-60% Passage**	**Avg. Flow (kcfs)**
June 1	0.404	6/9-8/2	83.1	0.359	6/28-7/9	38.1
June 8	0.386	6/24-8/16	57.4	0.188	6/30-7/22	39.6
June 15	0.315	7/5-8/20	47.3	0.148	7/4-8/11	35.2
June 22	0.277	7/30-9/1	38.0	0.093	7/18-9/3	28.0
June 29	0.193	8/4-9/28	29.8	0.051	8/10-9/20	23.6
July 6	0.134	8/11-10/15	27.2	0.022	8/19-9/30*	22.4

*For July 6, 2000, release assume 80% date 10 days later than that of June 29 release.



Page 32 Mainstem Spawning Rearing and Resting Habitat.

To prevent stranding of juvenile migrants and to maintain riparian community integrity, the Council should adopt firm flow protocols to minimize flow fluctuations. Dworshak releases should be ramped at a rate of 6 inches per hour as measured at the Clearwater gage below Dworshak Dam. At the Hells Canyon Complex, limit all flow reductions by ramping rates of no more than 6 inches per hour as measured at Lime Point. Such impacts have caused fishery managers to invoke ramping rate criteria to limit power peaking activities in tributaries to less than a two inch per hour change to shoreline areas (Hunter 1992). In the Hanford Reach, reduce power peaking from federal projects upstream to ramp flows a rate of no more than 2 inches per hour during the early emergence of Hanford fry (March 20- April 20). Power peaking can impact critical riparian habitat by limiting invertebrate production and diversity (Gislasen 1985) and is contrary to the normative river concept (Williams et al. 1996). Dramatic flow fluctuations from power peaking can strand juvenile salmon in shallow littoral areas causing direct mortality of hundreds of thousands of salmon (Hunter 1992; Wagner et al. 1999; Nugent et al. 2001).

Page 41 Research aimed at optimizing fish and wildlife benefits and energy.

The diagram poorly expresses the concept, since among other things transportation has been demonstrated to offer less survival effectiveness than other modes of passage. We recommend deleting the graph.

Page 43 Annual and in-season decision-making.

CRITFC recommends that the Council and CBFWA should jointly host:

1. Facilitated discussions of fish passage policy issues between all parties in the region, including the Council, federal agencies, fish and wildlife managers, power interests, fishery interests (or combine power & fishery into "public interests"), FPC, University of Washington, Streamnet, NOAA Science Center, etc. The intent of the facilitation should be to promote and encourage frank and open discussions of the issues by all interested stakeholders that would provide a basis for policy-making by the Council.

2. An ad hoc forum to address critical policy issues and solve problems relating to fish passage. The intent of the forum should be to seek consensus on policy recommendations to the Council, ensure a common understanding of the analyses and information that inform policy recommendations, and document and communicate to the public the purpose and basis of policy recommendations. Products would include policy recommendations to the Council and education and information materials for the Council and others on fish passage issues. Examples may include:
   - long term policy goals for system and in-river survival;
   - better integration and coordination of efforts (that are currently disjointed and not part of a clear overall strategy) to enhance mainstem survival, including system configuration, operations and R, M and E; and
   - workshops on important and timely fish passage issues to encourage and enable full consideration of the topics.

FERC Licensed Hydroprojects

Hells Canyon Complex

From the late 1980's until April 2001, BPA and Idaho Power Company (IPC) were engaged in annual exchange contracts for water and power. Typically, IPC would store water in the Hells Canyon Complex (Complex) in early spring and BPA would provide a power exchange to IPC. This storage would be released later in spring for salmon. The power generated from this release was sent back to BPA.

In the late summer, IPC would release storage and generate power, which would be sent to BPA. BPA would replace this power in September, which allowed IPC to store water to meet project elevations and assure that enough water was on hand for Hells Canyon fall chinook spawning.

In 1995, after release of the 1995-1998 FCRPS Biological Opinion, firm water exchange volumes and timing were established in contracts to meet Opinion RPAs. A five year contract was finalized for power and water exchanges in 1996. In early May, IPC would release 110 kaf, and send power to BPA. BPA would send the power back to IPC the latter half of May and refill the Complex. In summer, IPC would 1) release 237 kaf from the Complex and 2) shape and pass 427 kaf of Bureau of Reclamation water through the Complex. The power generated from these releases was sent to Bonneville. Bonneville would send exchange power for the 237 kaf to IPC in September and send exchange power for the 427 kaf back to IPC the following winter.

Because power markets are more lucrative in summer months, BPA claimed that IPC gained a substantial financial advantage in the contract arrangement. BPA negotiated with NMFS to have the power exchange contract omitted from the 2000 Biological Opinion and the five year contract expired on April 1, 2001. During 2001 negotiations with the federal operators, the CRITFC tribes, Oregon and Idaho all pressed BPA to renew the exchange contracts with IPC. BPA claimed that they were at a financial disadvantage, thus, were unwilling to renew the contract, despite long negotiations with IPC that involved the Idaho Governor's office.

Without the contract in place, there is no leverage to 1) assure that the 427 kaf or additional upper Snake water will be shaped and passed through the Complex, 2) assure that the 110 kaf and 237 kaf will be provided in a timely manner for fish. The result, as experienced last year, is that the fish do not get the water critical to their migrations, habitat and survival.

While IPC is undergoing relicensing of the Complex, and still has yet to comply with the ESA because of FERC's and the Administration's stance on ESA consultation for the Complex, there is no regional leverage to require IPC to release water for fish. Until re-licensing or separate litigation force IPC to comply with water releases, renewal of the BPA-IPC water exchange contract is critical to provide vital flows for listed Snake River chinook and steelhead and endangered Snake River sockeye.

The Council should adopt a measure that requires BPA and Idaho Power to establish a mutual agreeable power exchange contract that will result in the timely release of storage from the Hells Canyon Complex proper of 110 kaf in the spring, 237 kaf and the timely pass through of Bureau of Reclamation upper Snake storage. This measure should remain in effect until relicensing of the Complex is completed with the obligation to release flows for salmon a firm license requirement.

The Council should adopt a measure that requires the Corps of Engineers to use flexibility in flood control to allow the release of 110 kaf of storage from the Complex in the spring for salmon migrations.

The Council should adopt a measure that requires Idaho Power to fully develop measures, in consultation with tribes and fishery agencies as necessary for, 1) restoration of anadromy above the Complex, 2) selective release of cool water into the lower Snake River, 3) adequate flows for fall chinook spawning below the Complex and 4) abatement of total dissolved gas created by the Complex.

Mid Columbia Habitat Conservation Plan

The Council should adopt a measure that requires Chelan PUD and Douglas PUD and NMFS to fully examine and consider alternatives to the Mid-Columbia HCP that allow for protection of tribal treaty resources, in full consultation with affected tribes. The measure should specify that all regional parties must agree to the provisions of the HCP or alternative(s) to the HCP before it is implemented. Alternative measurement of performance, besides simple direct survival metrics must be a part of any long-term plan.

Rocky Reach

The Council should adopt a measure that requires Chelan PUD to consider all fish passage alternatives that best protect fish during relicensing,in addition to the new juvenile bypass system. Success of these passage measures should be evaluated using spawner to spawner evaluation tools. Spill should be incorporated to protect kelts and adults over the project. The Council should adopt a measure that requires Chelan PUD to examine adult losses using state- of- the- art telemetry methods. These losses should be compensated and potential passage problems in adult fishways should be investigated and remedied. Chelan PUD should expedite structural means to abate total dissolved gas from Rocky Reach.

Lake Chelan Hydroproject

The Council should adopt a measure that requires Chelan PUD to remedy water quality and flow impacts into the Chelan River from operation of the hydroproject during the relicensing term. Using empirical studies with salmon and a range of flows, Chelan PUD should fully explore the potential for the passage of anadromous fish, particularly sockeye, through the river and into Lake Chelan early during the new license.

Wells

The Council should adopt a measure that requires Douglas PUD to examine adult losses using state- of- the- art telemetry methods. These losses should be compensated and potential passage problems in adult fishways should be investigated and remedied.

Rock Island

The Council should adopt a measure that requires Chelan PUD should expedite structural means to abate total dissolved gas from Rocky Reach. The provisions of the Rock Island Settlement Agreement should stand unless all parties to that Agreement concur that a modification of the agreement is warranted.

Priest and Wanapum

The Council should adopt a measure that requires Grant PUD to establish interim relief for anadromous salmon in consultation with tribes and fishery agencies. This relief should include but not be limited to, 1) expedited development of surface bypass systems, 2) full 2000 Memorandum of Agreement spill, 3) expedited structural remedies for fishways, 4) planning for production facilities for salmon, sturgeon and lamprey and implementation of improvements for the Priest Rapids Hatchery, 4) funding of studies to evaluate impacts of power peaking on salmon and salmon habitat in the Hanford Reach, and 5) reduction of power peaking in the Hanford Reach.

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GENESYS Hydro Analysis of NPPC Mainstem Amendment Proposal…**corrected**

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February 14th, 2003

Introduction

The spreadsheets that accompany this memo summarize the GENESYS studies of the CRITFC Natural River Plan, the NPPC Mainstem Amendment Proposal, and the 2000 NOAA Fisheries Biological Opinion. This memo seeks to guide the reader through the extensive analysis.

Summary of Proposed Operations

The CRITFC Natural River Plan (Figure 1; CRITFC 1995), is driven by Altered Flood Control operations at Grand Coulee, Dworshak, Brownlee, Hungry Horse, Libby, Arrow, and Mica plus earlier refill (May 31st, not June 30th) whenever possible (Martin 2003). The main objective is to create a natural peaking flow regime (Williams et al., 1996; Bunn and Arthington 2002). The risk of exceeding bankfull (450 kcfs) or flood flow (550 kcfs) at The Dalles with the CRITFC plan is 43% (bankfull) and 16% (flood flow), respectively, compared with 41% (bankfull) and 14% (flood flow) for Federal operations (Figures 2, 3). Hungry Horse and Libby operations are very similar to VAR-Q, but do not use the compensating drafts at Grand Coulee. The Coulee operation in July drafts the lake only 1-foot to benefit resident fish in high-to-medium water years and drafts 10-feet to benefit salmon in low water years then reaches elevation 1283 by September 30th. The 2 MaF pre-season draft at Libby is reduced to 1.75 MaF or to elevation 2424 feet. Total summer flow augmentation is 3.377 MaF. Upper Snake flow augmentation is 1.877 MaF (427 KaF, 450 KaF from Brownlee, and 1 MaF from the Upper Snake). In reality, only 600 to 700 KaF will physically appear from the Upper Snake, as upstream diversions complicate the analysis. Upper Columbia flow augmentation includes all Non-Treaty Storage, 1 MaF, and 500 KaF from Banks Lake. The Nez Perce Tribe-Idaho Plan for Dworshak specifies full in July (except for a 10 foot draft in July for the 14 lowest water years to enhance water quality), draft 1 MaF during August, and draft 200 KaF in September.

The NPPC Plan is described elsewhere but relies on the elimination of flow targets, spring flow augmentation, and the April 10th refill requirement (countered by 95% refill by June 30th). Snake flow augmentation of 427 KaF is assumed. The GENESYS model output file (October 23, 2002, 1:20 pm) was provided by the NPPC. Multiple versions of the NPPC plan hindered the analysis so the above mentioned version was used.

The NOAA Fisheries 2000 Biological Opinion was modeled by NPPC staff. Like the NPPC study, the Biological Opinion model output changes depending on which version is examined. So, the NPPC GENESYS model output file of October 23, 2002, 12:55 pm was used.

Methodology

Water years 1929-1978 used in the GENESYS modeling (version 2.6.1) were run sequentially. For the CRITFC study, 2000 Biological Opinion spill levels are used, rather than CRITFC spill levels, for an "apples-to-apples" comparison with the NPPC and Biological Opinion operations. CRITFC emphasizes a multi-class water year approach with attention to the low years.

Results and Discussion

Flow

The Executive Summary (GENESYS hydro analysis spreadsheet) shows that the NPPC plan, on average, gives 190 cfs (lower Snake) and 2610 cfs (lower Columbia) less spring flow, relative to the Biological Opinion flows. Summer flows decline by 340 cfs (lower Snake) to 5550 cfs (lower Columbia), relative to the Opinion. The CRITFC plan gives 4500 cfs more lower Snake spring flow relative to the Biological Opinion and a 150 cfs decrease in summer flow, or a 1150 cfs increase if September is included (ignored by the Biological Opinion) to help adult salmon. CRITFC's lower Columbia flows show 10,800 cfs more during spring and 4960 cfs during summer (or 8290 cfs if September is included).

For low years, the NPPC plan gives 620 cfs (lower Snake) and 7860 cfs (lower Columbia) less spring flows than Biological Opinion flows. Summer flows drop by 1970 cfs (lower Snake) and 6900 cfs (lower Columbia), relative to the Biological Opinion.

In low years, the CRITFC plan gives 3900 cfs (lower Snake) and 11,110 cfs (lower Columbia) more spring flow relative to the Biological Opinion. Summer lower Snake flows drop by 3100 cfs but only drop by 1680 cfs if September is included. Summer lower Columbia flows drop by 140 cfs, but increase by 3180 cfs if September is included to help adult salmon.

The URC-NPPC spreadsheet shows storage benefit obtained from CRITFC's Altered Flood Control operation. For the 50-water year average, the CRITFC plan leaves **16 MaF** more storage in the previously mentioned reservoirs on average relative to current Federal operations.

However, looking at seasonal flow values is misleading—the total hydrograph should be examined. The natural flushing action of the CRITFC plan is evident even in low water years.

Spill

Values presented in the Executive Summary represent the sum total of spill (forced and bypass) of the four lower Snake projects and four lower Columbia projects. Values are pro-rated, given the monthly time step model output and correspond to Biological Opinion season start/end dates.

The NPPC plan, on average, reduces lower Snake spring spill by 40 cfs relative to the Biological Opinion and by 610 cfs in the lower Columbia. The NPPC plan reduces summer spill by 100 cfs in the lower Snake and 1840 cfs in the lower Columbia. The CRITFC plan gives 4970 cfs more lower Snake spring spill and 22,210 cfs more lower Columbia spill, relative to the Biological Opinion. Summer spill increases by 350 cfs (lower Snake) and 14330 cfs (lower Columbia), or 9750 cfs if September is included, relative to the Biological Opinion.

Probability of Meeting Flow Objectives

For Lower Granite, the CRITFC plan gives, on average, a 56% chance in late April and 80% chance in May of meeting spring Biological Opinion flows, versus a 52-54% and 72% chance, respectively, for the NPPC plan or Biological Opinion. The CRITFC plan offers a 40% chance in July, versus a 50% chance for the NPPC plan and 70% chance for the Biological Opinion.

For McNary, the CRITFC plan gives a 52% chance in late April and 84% chance in June of meeting spring Biological Opinion flows, versus the 50% and 72-74% chance for the NPPC plan or Biological Opinion. The CRITFC plan offers a 50% chance in July, versus a 44% chance for the NPPC plan and 52% for the Biological Opinion. CRITFC does not subscribe to the flat Biological Opinion target flow concept, so any comparisons here are for the benefit of the Biological Opinion. In short, the NPPC plan may equal, but is usually below, in its chances to meet the Biological Opinion target flows, especially during summer for the lower Columbia.

Reservoir Elevations

The April 15th model output suggests the effects of removing the April 10th flood control refill requirement. The NPPC plan would have, on average, Hungry Horse lower by 1.2 feet, Libby lower by 0.2 feet, Grand Coulee lower by 5 feet, and Dworshak lower by 2.8 feet, relative to the Biological Opinion. For low years, the NPPC plan would have Hungry Horse lower by 1.8 feet, no change at Libby, Grand Coulee lower by 16.4 feet, and Dworshak lower by 10.4 feet.

For April 10th refill, the CRITFC plan would have, on average, Hungry Horse lower by 1.3 feet, Libby higher by 5.2 feet, Grand Coulee higher by 20.3 feet, and Dworshak higher by 27.2 feet, relative to the Biological Opinion. For low years, the CRITFC plan would have Hungry Horse lower by 1.3 feet higher, Libby higher by 13.1 feet, Grand Coulee higher by 11.9 feet, and Dworshak lower by 1.3 feet, relative to the Biological Opinion.

For August 31st, the NPPC plan would have, on average, Hungry Horse higher by 8.5 feet, Libby higher by 6.2 feet, Grand Coulee higher by 3.5 feet, and Dworshak higher by 3.2 feet, relative to the Biological Opinion. For low years, the NPPC plan would have Hungry Horse higher by 8.4 feet higher, Libby higher by 3 feet, Grand Coulee higher by 5 feet, and Dworshak higher by 17.6 feet, relative to the Biological Opinion.

For August 31st, the CRITFC plan would have, on average, Hungry Horse higher by 1.2 feet, Libby higher by 6.3 feet, Grand Coulee higher by 3 feet, and Dworshak lower by 1.3 feet, relative to the Biological Opinion. For low years, the CRITFC plan would have Hungry Horse higher by 2.8 feet, Libby higher by 2.6 feet, Grand Coulee higher by 2 feet, and Dworshak higher by 21.2 feet, relative to the Biological Opinion.

Retention Time

Retention time refers to the "turnover" time in a reservoir and is related to nutrients and resident fish populations. Retention time is calculated by averaging the storage contents of the current and past month, plus the 'dead' (i.e., non-operational) storage value, divided by the flow.

For the summer season, the NPPC plan would have, on average, 121 more days at Hungry Horse, 24.4 more days at Libby, 2.1 more days at Grand Coulee, and 15.5 more days at Dworshak, relative to the Biological Opinion. The CRITFC plan would have, on average, 16.8 more days at Hungry Horse, 10.2 more days at Libby, 1.5 less days at Grand Coulee, and 97.5 more days at Dworshak, relative to the Biological Opinion. The NPPC plan gives the most benefit to Hungry Horse and Libby while the CRITFC plan gives the most benefit to Dworshak.

System Generation

The NPPC plan offers, on average, a 468 MW increase in total annual generation, relative to the Biological Opinion and would produce $10 to $13 million per year or cost $29 million per year, depending on the water year. CRITFC's plan, on average, produces 243 MW less in total annual generation, relative to the Biological Opinion and would produce $17 million per year (or $255 million in an unusual power market such as 2000) or cost $32 million per year, depending on the water year, relative to the Biological Opinion spill values. CRITFC's plan gives more generation in June, July, later half of August, and September, relative to the Biological Opinion. The NPPC plan shifts generation from spring and summer to winter (December through March) with a 100 MW to 1300 MW reduction in generation during spring and summer months.

Water Supply Forecast Correction Curves

In addition to using Altered Flood Control, other new water management tools should be implemented to better manage Columbia basin water. A problem for water managers is relying on Water Supply Forecast (WSF) information so early in the season, then engaging in hydro operations (e.g., chum flows) that deplete system storage that is needed for spring flows. If the WSF volumes decline, then Federal operators are very unlikely to replenish that water in the reservoirs for spring salmon flows. New research by CRITFC staff shows how trending analysis can value-enhance the WSFs and save water in medium-low and low water year classes (Martin 2002). This knowledge would keep more water in the reservoirs in low and drought-prone *El Nino* water years.

For example, during this *El Nino* year, the January 1st WSF released by the NWS and NRCS is for 80.5 MaF forecast (January-July) for the Columbia at The Dalles. Using the correction curve method, this forecast becomes 65 MaF. The February Final forecast issued by the NWS and NRCS is 75.6 MaF and will likely to converge on the 67 MaF value (corrected for the February Final WSF) issued by CRITFC. Such knowledge given early in the season could prevent over drafting of storage reservoirs due to flood control and the savings in water would be used for spring and summer fish operations.

Summary

The NPPC plan reduces spring/summer flows, shifts flow from summer to winter with a muted hydrograph like that of the Biological Opinion. NPPC spill values are 100 to 1800 cfs less than Biological Opinion operations. With the 95% chance of refill by June 30th, the NPPC plan would miss elevations by 0.2 to 1.6 feet. NPPC pool elevations would be 0.2 to 5 feet lower by April 15th (and up to 10.4 feet lower in low years) and higher by 3.2 to 8.5 feet by August 31st (and 3 to 17.6 feet higher in low years), relative to the Biological Opinion.

The shift in flow from spring/summer to winter would be a disadvantage to salmon with only an incremental annual total system-generation benefit, which may produce $10 to $13 million or cost $30 million of hydro-generation revenue, depending on the water year. The CRITFC plan gives more flow and spill in a timely manner for salmon and is balanced with resident fish (i.e., higher resident times) and leaves 16 MaF more water in six reservoirs due to Altered Flood Control, which takes advantage of global warming.

Attachments:
Hydro spreadsheet (GENESYS Hydro analysis) and Flood Control spreadsheet (URC-NPPC)

References:

Bunn, S.E. and A.H. Arthington. 2002. Basic Principles and Ecological Consequences of Altered Flow Regimes for Aquatic Biodiversity. Environmental Management, Vol. 30(4), pp. 492-507.

CRITFC—Columbia River Inter-Tribal Fish Commission (Nez Perce, Umatilla, Yakama and Warm Springs Tribes). 1995. *Wy-Kan-Ush-Mi Wa-Kish-Wit (Spirit of the Salmon).* The Columbia River anadromous fish restoration plan. Columbia River Inter-Tribal Fish Commission. Portland, Oregon. (http://www.critfc.org/text/trp.html)

Martin, K. 2002. Water Supply Forecast Correction Curves. Presentation given to the Oregon Chapter of the American Meteorological Society, November 21, 2002, Portland, Oregon. (http://www.critfc.org/)

Martin, K. 2003. Altered Flood Control, Climate Change, and Rebuilding Pacific Northwest Salmon Stocks. Columbia River Inter-Tribal Fish Commission. Portland, Oregon. (http://www.critfc.org/text/nat_riv.html)

Williams, R., and eleven co-authors. 1996. *Return to the River*. Restoration of salmonid fishes in the Columbia River Ecosystem. Northwest Power Planning Council. Portland, Oregon. (http://www.nwcouncil.org/library/return/2000-12.htm)

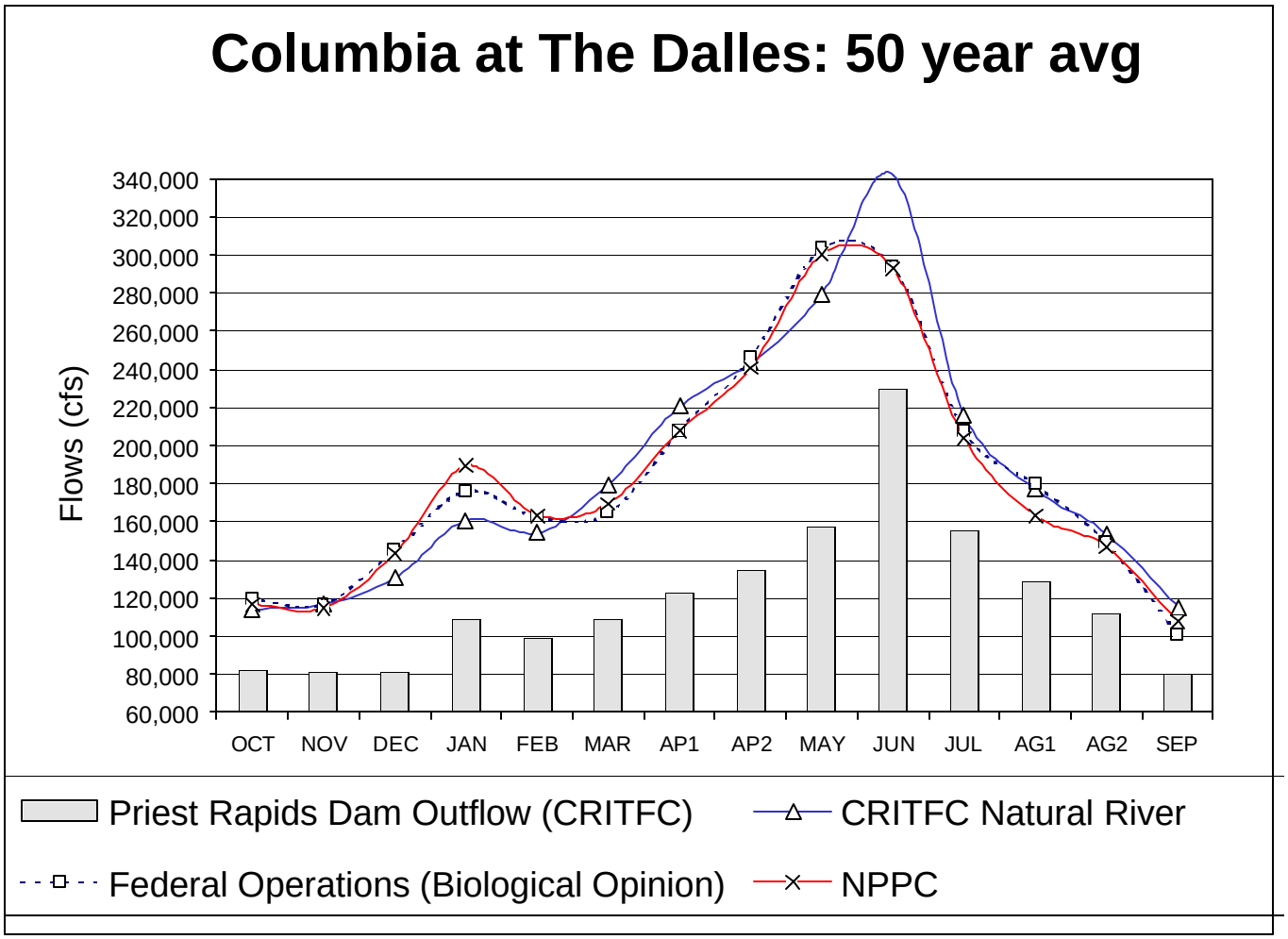

Figure 1. Summary Hydrographs for the NPPC versus CRITFC plans, relative to 2000 Biological Opinion operations.

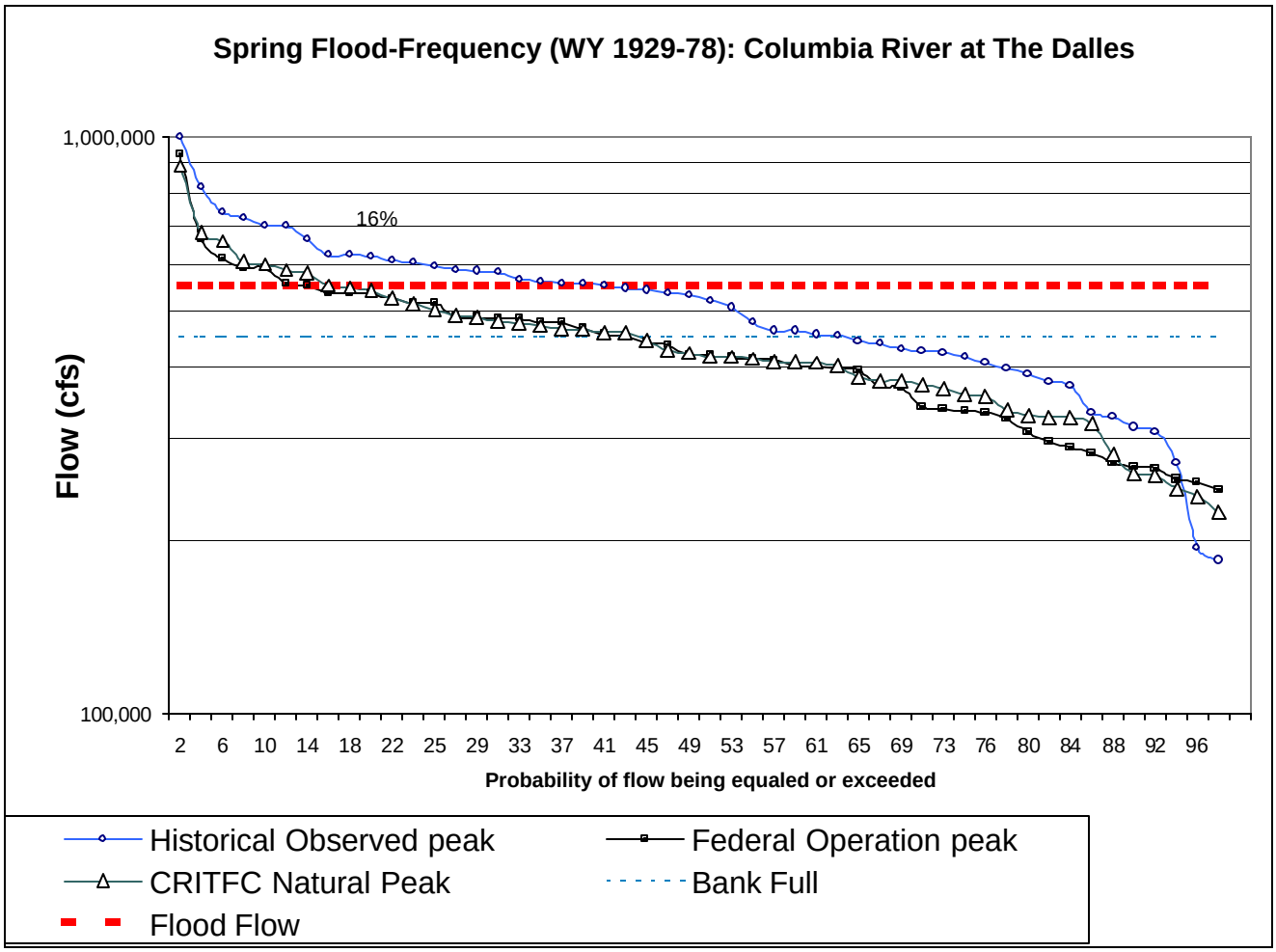

Figure 2. Flood frequency analysis for the CRITFC plan, relative to Federal operations.

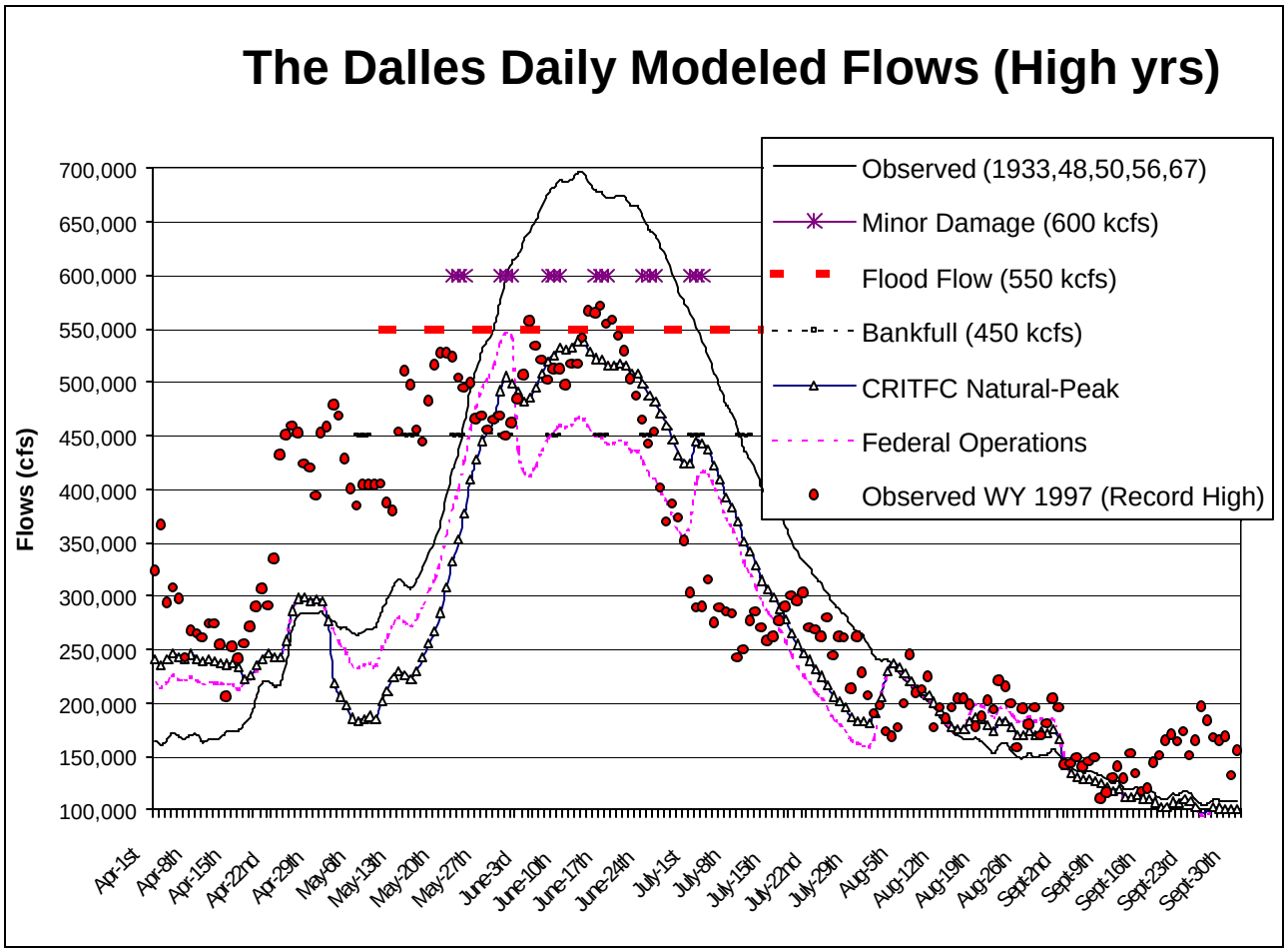

Figure 3. Flood risk for the CRITFC plan, relative to Federal operations, using GENESYS monthly model data disaggregated into daily data.

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MEMORANDUM

TO: Michele DeHart

FROM: David A. Benner

DATE: December 9, 2002

RE: NWPPC Mainstem Amendment Analysis Review

At your request, I have reviewed the draft Northwest Power Planning Council Fish and Wildlife Program Amendment Analysis. As a part of this review, I have compared the NWPPC analysis to a similar analysis conducted by the Bonneville Power Administration (BPA). In addition, I have utilized the flow travel time relationships developed from monitoring programs and research studies.

The Main Points of this investigation are as follows:

Lower Granite

- During an average water year, the NWPPC amendment would result in lower flows at Lower Granite from April 16 to August 15. During July, flows are continuously expected to be 1,528 cfs lower relative to 2000 Biological Opinion operations, a total loss of water of 93.8 Kaf.
- In low water years, the NWPPC Plan would result in continuously decreased discharges of 7,213 cfs in July, a total loss of water of 442.7 Kaf. During WY 2000 (relatively low water year during period of BiOp implementation), discharges in July averaged 37,800 cfs; if the NWPPC Plan had been in effect, flows would have been 30,587 cfs, a 19% decrease. This flow decrease would result in an estimated average increase of approximately 14% in subyearling chinook travel times between Lower Granite Dam and McNary.
- During average, median, and low water years at Lower Granite, the NWPPC Plan would shift 113.6, 177.0, and 473.1 Kaf of water out of the time period between July 1 and August 15 (according to NWPPC results).
- According to BPA modeling results, during low water years at Lower Granite the month of May could expect a drop in monthly average discharge of 1,600 cfs if the NWPPC plan were instituted, a volume loss of 98.2 Kaf. Additionally, BPA results indicate that

during average water years, monthly discharges could be expected to drop between 300 and 900 cfs between April 16th and the end of June.

McNary

- During an average water year, the NWPPC amendment would result in lower flows at McNary from April 16 to August 31. During the first half of August, flows are expected to be 16,468 cfs lower at McNary, relative to operations resulting from the 2000 Biological Opinion, a total loss of water of 489.1 Kaf. During the summer of 2002, an approximately average water year, discharges averaged 156,600 cfs at McNary between August 1-15; if the NWPPC Plan would have been in effect, flows would have been 140,132 cfs, an 11% decrease. This flow decrease would result in an estimated average increase of approximately 13% in subyearling chinook travel times between McNary and John Day Dam.
- In low water years, the NWPPC Plan would result in decreased discharges of 22,618 cfs in the second half of April and 17,431 cfs in July. During WY 2000 (relatively low water year during period of BiOp implementation) discharges averaged 297,500 cfs in the second half of April and 166,700 cfs in July; if the NWPPC Plan had been in effect, flows would have been 274,882 cfs in the second half of April and 149,269 cfs in July, decreases of 7.6% and 10.5%, respectively. In the second half of April, this flow decrease would result in steelhead and chinook travel time increases between McNary and Bonneville of approximately 7%. In July, the flow decrease would lead to an estimated average increase of 10% in subyearling chinook travel times between McNary and John Day Dam.
- During average, and low water years at McNary Dam, the NWPPC Plan would shift 392.4 and 936.5 Kaf of water out of the time period between April 16 and June 30th (according to NWPPC results). Additionally, during average, median, and low water years at McNary, the NWPPC Plan would shift 712.2, 1094.9, and 1468.6 Kaf of water out of the time period between July 1 and August 15. Overall, between April 16 and August 15, 1104.6 Kaf of water would be lost during average water years and 2405.1 Kaf would be lost during low water years, relative to the Biological Opinion. The original Fish and Wildlife Water Budget contained 3500 Kaf for flow augmentation; therefore, during low water years nearly 70% (2405.1Kaf/3500Kaf) of the original water budget volume of water would be transferred out of the period between April 16 to August 15.
- During average, median, and low water years between April 16-30 discharges would decrease between 9,376 and 3,144 cfs relative to the pre-water budget period at McNary. This suggests that the NWPPC Plan would lead to a decay in April 16-30 flows, beyond that of the pre-water budget years.
- According to BPA model results at McNary, during low water years the second one-half of April could experience discharges 63,500 cfs less if the NWPPC Plan were implemented as compared to the BiOp, a total loss of 1886.0 Kaf of water. Also, during low water years, discharges are predicted by BPA to be between 4,500 and 12,900 cfs less between May and July if the NWPPC plan is instituted. Additionally, BPA results indicate that during average water years monthly discharges could be expected to drop

between 2,900 and 24,300 cfs between April 16th and the end of July, again with the most significant drop in discharge in the second half of April.

- Both the NWPPC and the BPA models agree that severe decreases in discharges can be expected at McNary Dam if the NWPPC Mainstem Amendment is implemented.

The NWPPC used data from water years 1929 to 1978 to model the impact of the "Council Preferred Alternative" on spring/summer flows and refill probabilities relative to that of the current NMFS 2000 Biological Opinion and that of the pre-water budget years. According to John Fazio, the NWPPC constrained the analysis to the mentioned water years due to a lack of system data from BPA, from whom the NWPPC gets data. Consequently, the NWPPC could not use COE data that uses observed runoff to calculate flood control elevations, as compared to BPA, which uses water supply forecasts to evaluate flood control points. Because the NWPPC agrees with BPA in terms of determining flood control based upon water supply forecasts, the NWPPC elected to use only the data that BPA had readily available.

More than the last twenty water years have been excluded from the NWPPC council analysis. The 20%, 50%, and 80% exceedence January-July runoff volumes at Lower Granite and The Dalles were calculated over the span of years between 1929-1978 and over 1929-2001; in effort to evaluate how the selection of limited water years may influence the magnitude of exceedence runoff volumes (Table 1).

Table 1. The 80%, 50%, and 20% exceedence runoff volumes (January-July) at Lower Granite and The Dalles between 1929-1978 and 1929-2001.

	LGR (Jan-July, Maf)		TDA (Jan-July, Maf)	
	1929-1978	1929-2001	1929-1978	1929-2001
80% Exceedence	20.4	19.9	83.0	82.1
50% Exceedence	28.5	26.7	106.8	104.5
20% Exceedence	35.5	36.8	119.5	122.6

From Table 1, both the 80% and 50% exceedence runoff volumes (lower water years) at The Dalles and Lower Granite decreased when the entire record (1929-2001) was used as compared to the record used by the NWPPC (1929-1978). Alternatively, the 20% Exceedence runoff volumes (higher water years) increased when the entire record (1929-2001) was used as compared to the record used by the NWPPC (1929-1978). It appears that the years between 1979 and 2001 contain relatively extreme water years, which tend to extend both the lower and upper exceedence runoff volumes.

The following sections will focus on evaluating the spring and summer month-to-month differences in discharge at both Lower Granite and McNary that could occur as a result implementing the NWPPC's Preferred Alternative. The NWPPC modeled monthly discharges at LGR and McNary under three scenarios 1) The current Biological Opinion 2) The NWPPC Preferred Alternative 3) The operation in effect before the Water Budget. All subsequent

analyses by FPC used the model results provided in the original NWPPC Draft Amendment spreadsheet, which can be found at *http://www.nwcouncil.org/library/2002/2002-16/modeling.htm*. Additionally, NWPPC month-to-month results were compared to similar analyses conducted by BPA.

Monthly differences in discharge were quantified in two ways 1) the difference in discharge that would occur if the NWPPC Amendment were adopted, relative to the operation called for in the Biological Opinion and 2) the difference in discharge that would occur if the NWPPC Plan were adopted, relative to the hydrosystem operation in effect before the water budget. All differences in monthly discharges were calculated for the average, median, 20% exceedence, and 80% exceedence runoff volumes for the water years comprising the data set from 1929 to 1978. Again, all numbers were taken directly from the NWPPC Draft Amendment Analyses.

Table 2 and Figure 1 display the month-to-month differences in discharge at Lower Granite that could be expected during varying water years if the NWPPC Plan were implemented, relative to the operation of the Columbia hydrosystem under the Biological Opinion operations. During an average water year, the NWPPC amendment would result in lower flows at Lower Granite from April 16 to August 15. During July, flows are expected to be 1,528 cfs lower at Lower Granite, relative to operations resulting from the 2000 Biological Opinion. During the summer of 2002, an approximately average water year, discharges averaged 38,300 cfs at Lower Granite; if the NWPPC Plan would have been in effect, flows would have been 36,772 cfs, a 4% decrease.

In low water years (80% Exceedence), the NWPPC Plan would result in discharges decreased 7,213 cfs in July. From Table 1, an 80% Exceedence water year between 1928 and 2001 had a January-July runoff volume of 19.9 Maf at Lower Granite. Water year 2000 contained a runoff volume of 24.6 Maf at Lower Granite, which was the closest volume to the historical 80% Exceedence runoff volume during the period of Biological Opinion implementation. During WY 2000 discharges in July averaged 37,800 cfs; if the NWPPC Plan had been in effect, flows would have been 30,587 cfs, a 19% decrease. The following multiple regression equation was developed ($p<0.001$, $R^2 = 0.59$) using information from Table 32 (Page 74) of the 2001 Annual Report of the Fish Passage Center:

$$\text{Subyearling Chinook Travel Time from Lower Granite to McNary} = 21.693 - 0.295\,(\text{Date}) + 484.186/\text{Flow}$$

Where,

Date = day subsequent to June 1
Flow = Discharge, kcfs

Using this equation, it was estimated that the NWPPC Plan would lead, on average, to an approximate 14% increase in subyearling chinook travel time from Lower Granite to McNary if average monthly July flows decreased from 37,800 cfs to 30,587 cfs.

Overall, the NWPPC plan would have the largest impact upon Lower Granite discharges during July and early August.

Table 2. Monthly and bi-monthly differences in discharge at Lower Granite that could be expected for varying water years if the NWPPC preferred alternative were implemented, differences are relative to the current Biological Opinion operations.

Date	Average WY Discharge (cfs)	Median WY Discharge (cfs)	80% Exceedence (Low WY) Discharge (cfs)	20% Exceedence (High WY) Discharge (cfs)
April 16-30	-316	-72	0	0
May	-205	0	0	0
June	-199	0	0	0
July	-1528	-2657	-7213	4700
Aug 1-15	-666	-469	-1021	-394
Aug 16-31	2185	-201	6594	-570

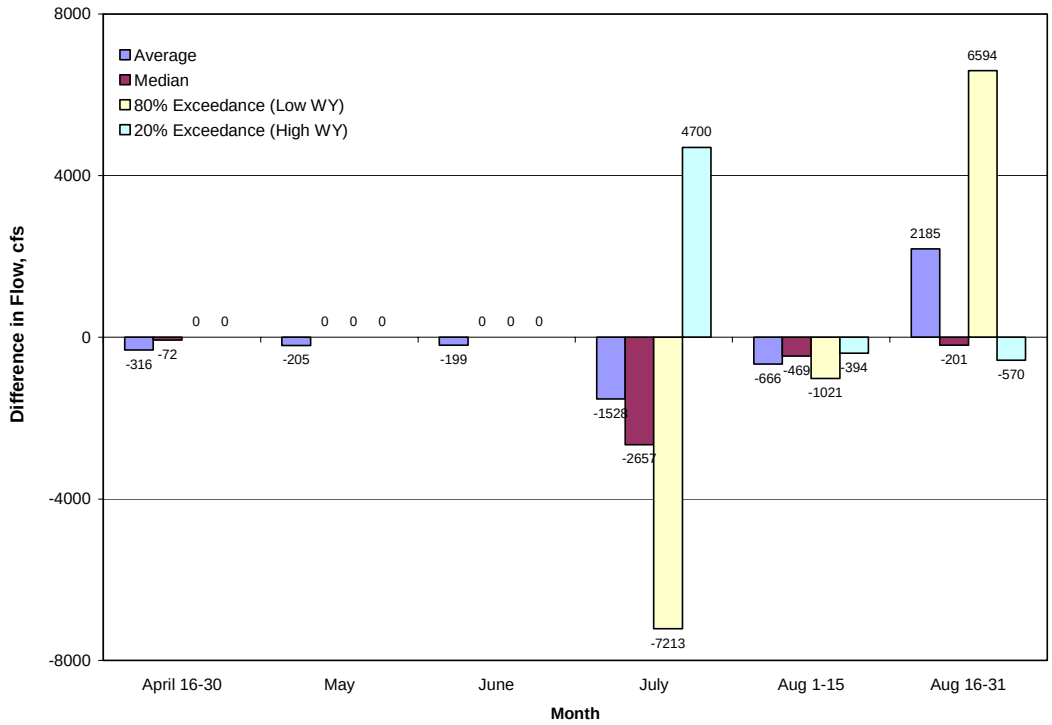

Figure 1. Monthly and bi-monthly differences in discharge at Lower Granite that could be expected for varying water years if the NWPPC preferred alternative were implemented, differences are relative to the current Biological Opinion operations. Negative values indicate less discharge would occur under the NWPPC Plan, positive values indicate greater discharge would occur under the NWPPC Plan, and zero values indicate no change in discharge would be expected.

Table 3 and Figure 2 display the month-to-month differences in discharge at Lower Granite that could be expected during varying water years if the NWPPC Plan were implemented, relative to pre-water budget operations. As would be expected, month-to-month discharges at Lower Granite resulting from the NWPPC Plan would be increased over all periods between April 16 and August 31, relative to pre-water budget operations.

Table 3. Monthly and bi-monthly differences in discharge at Lower Granite that could be expected for varying water years if the NWPPC preferred alternative were implemented, differences are relative to the current pre-water budget operations.

Date	**Average WY Discharge (cfs)**	**Median WY Discharge (cfs)**	**80% Exceedence (Low WY) Discharge (cfs)**	**20% Exceedence (High WY) Discharge (cfs)**
April 16-30	5258	8235	4026	4213
May	3644	1516	5278	2935
June	1692	2992	2770	255
July	11613	11535	11011	12666
Aug 1-15	12429	13228	11992	12171
Aug 16-31	13494	12970	13669	14434

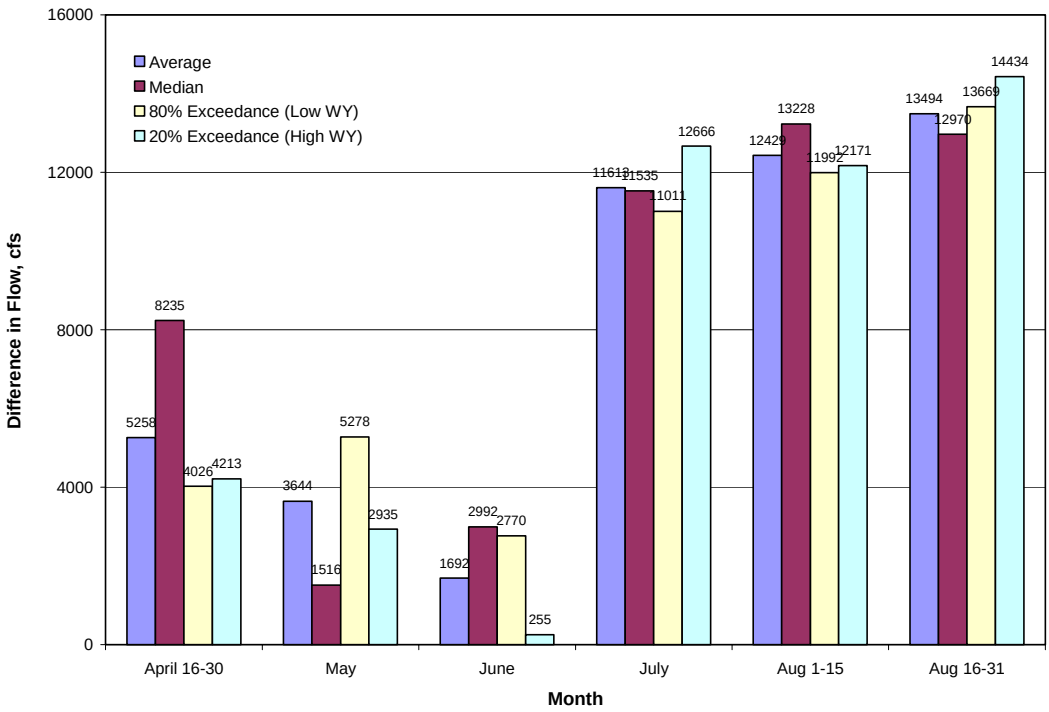

Figure 2. Monthly and bi-monthly differences in discharge at Lower Granite that could be expected for varying water years if the NWPPC preferred alternative were implemented, differences are relative to the current pre-water budget operations. Negative values indicate less discharge would occur under the NWPPC Plan, positive values indicate greater discharge would occur under the NWPPC Plan, and zero values indicate no change in discharge would be expected.

The BPA conducted separate modeling which was useful in comparing the differences in monthly discharge that could be expected if the NWPPC Plan were implemented as compared to the operation of the hydrosystem under the BiOp. BPA modeled monthly flows at Lower Granite and McNary under the following scenarios:

1) **2000 Biological Opinion**: Base Case; Target chum flows from November 1-14 (125 kcfs), November 15-December 31 9145 kcfs); operate reservoirs to respective confidence levels of being at URC on April 10 then refill by June 30, meet summer flow targets with reservoir drafts limited per the BiOp
2) **Alternative 1**: 95% confidence of refill by June 30th is the primary operational objective. Target chum flows November 1-Decembber 31 (125 kcfs); operate reservoirs no lower than the 95% confidence criteria allows; meet summer flow targets with reservoir drafts limited per the BiOp
3) **Alternative 2**: 95% confidence of refill by June 30th is the primary operational objective. Target chum flows November 1-Decembber 31 (125 kcfs); January 1-March 31 meet a minimum flow of 125 kcfs for chum but operate reservoirs no lower

than the 95% confidence criteria allows; meet summer flow targets with reservoir drafts limited per the BiOp

According to the Summary of Modeling Assumptions for Mainstem Hydro Operations found at http://www.nwcouncil.org/library/2002/2002-16/modeling.htm, which compares Biological Opinion operations to the NWPPC proposed alternative operations, the BPA Alternative #1 was selected to best represent the NWPPC plan. The output for BPA modeling contained monthly flow differences between the operations of the BiOp and Alternative 1 (NWPPC Plan) for each water year between 1929 and 1978 (same data set used by the NWPPC). Table 1 was utilized to determine the 20%, 80%, and median exceedence runoff volumes between 1929 and 1978. The complete dataset of runoff volumes (Jan-July) throughout the period between 1929-1978 was used to identify water years with similar runoff volume as each of the exceedence runoff values. Table 4 displays the month-to-month differences in discharge at Lower Granite that could be expected during varying water years if the NWPPC Plan were implemented, relative to the operation of the Columbia hydrosystem under the Biological Opinion operations, as presented by BPA. The BPA predicted that discharges would not be influenced largely at Lower Granite as a result of the implementation of the NWPPC operational plan. According to BPA modeling results, during low water years the month of May could expect a drop in monthly average discharge of 1,600 cfs if the NWPPC plan were instituted. Additionally, BPA results indicate that during average water years, monthly discharges could be expected to drop between 300 and 900 cfs between April 16th and the end of June.

Table 4. Monthly and bi-monthly differences in discharge at Lower Granite that could be expected for varying water years if the NWPPC preferred alternative were implemented, differences are relative to the hydrosystem under Biological Opinion operations. Analyses presented by the Bonneville Power Administration.

Date	Average WY Discharge (cfs)	Median WY, 1953 Discharge (cfs)	80% Exceedence (Low WY, 1945) Discharge (cfs)	20% Exceedence (High WY, 1959) Discharge (cfs)
April 16-30	-900	-600	200	0
May	-300	0	-1600	0
June	-300	0	0	0
July	100	0	400	0
Aug 1-15	0	0	0	0
Aug 16-31	-100	0	0	0

Table 5 and Figure 3 display the month-to-month differences in discharge at McNary that would be expected during varying water years if the NWPPC Plan were implemented, relative to Biological Opinion operations. During an average water year, the NWPPC amendment would result in lower flows at McNary from April 16 to August 31. During the first half of August, flows are expected to be 16,468 cfs lower at McNary, relative to operations resulting from the 2000 Biological Opinion. During the summer of 2002, an approximately average water year, discharges averaged 156,600 cfs at McNary between August 1-15; if the NWPPC Plan would

have been in effect, flows would have been 140,132 cfs, an 11% decrease. The following multiple regression equation was presented in Berggren and Filardo (1993) ($p<0.001$, $R^2 = 0.65$):

Subyearling Chinook Travel Time from McNary to John Day
= -42.364 + 0.165 (Date) + 0.133(DFlow) + 3016.061(1/Flow)

Where,

Date = Day subsequent to January 1
DFlow = Absolute change in daily average flow (kcfs) over travel time days
Flow = Discharge, kcfs

Using this equation, it was estimated that the NWPPC Plan would lead, on average, to an approximate 13% increase in subyearling chinook travel time from McNary to John Day if flows between August 1-15 decreased from 156,600 cfs to 140,132 cfs.

In low water years (80% Exceedence), the NWPPC Plan would result in decreased discharges of 22,618 cfs in the second half of April and 17,431 cfs in July. From Table 1, an 80% Exceedence water year between 1928 and 2001 had a January-July runoff volume of 82.1 Maf at The Dalles. Water year 2000 contained a runoff volume of 98 Maf at Lower Granite, which was the closest volume to the historical 80% Exceedence during the period of Biological Opinion implementation. During WY 2000 discharges averaged 297,500 cfs in the second half of April and 166,700cfs in July; if the NWPPC Plan had been in effect, flows would have been 274,882 cfs in the second half of April and 149,269 cfs in July, decreases of 7.6% and 10.5%, respectively.

Using 1999-2002 springtime yearling chinook and steelhead travel time and discharge data, the following relationships were calculated:

Yearling chinook travel time between McNary and Bonneville =
579.06 * (Flow)^-0.818

Yearling steelhead travel time between McNary and Bonneville =
874.54 * (Flow)^-0.907

Where:

Flow = the average discharge at McNary, The Dalles, and John Day over the travel time period, kcfs

Assuming that the discharges at McNary that would result from the NWPPC plan and the BiOp would be approximately equal to the average discharge across McNary, The Dalles, and John Day over the same period, it was estimated that the NWPPC Plan would lead, on average, to approximately 7% increases in yearling chinook and steelhead travel times between McNary and Bonneville if average flows in second half of April decreased from 297,500 cfs to 274,882 cfs.

Additionally, the following multiple regression equation, presented in Berggren and Filardo (1993) ($p<0.001$, $R^2 = 0.65$), was utilized to determine the increase in travel times associated with decreasing July flows from 166,700 cfs to 149,269 cfs during relatively low water years:

$$\text{Subyearling Chinook Travel Time from McNary to John Day} = -42.364 + 0.165\,(\text{Date}) + 0.133(\text{DFlow}) + 3016.061(1/\text{Flow})$$

Where,

Date = Day subsequent to January 1
DFlow = Absolute change in daily average flow (kcfs) over travel time days
Flow = Discharge, kcfs

Using this equation, it was estimated that the NWPPC Plan would lead, on average, to an approximate 10% increase in subyearling chinook travel time from McNary to John Day if average monthly July flows decreased from 166,700 cfs to 149,269 cfs.

Overall, the NWPPC plan would lessen flows (relative to the BiOp) at McNary continuously from April 16 to August 31 during average water years with the largest impact during the first part of August. During low water years, discharges would decrease significantly more than 10,000 cfs for two months (April 16-30, July, and Aug 1-15).

Table 5. Monthly and bi-monthly differences in discharge at McNary that could be expected for varying water years if the NWPPC preferred alternative were implemented, differences are relative to the current Biological Opinion operations.

Date	**Average WY Discharge (cfs)**	**Median WY Discharge (cfs)**	**80% Exceedence (Low WY) Discharge (cfs)**	**20% Exceedence (High WY) Discharge (cfs)**
April 16-30	-5174	0	-22618	0
May	-2835	1	-1578	0
June	-1089	0	-2827	-3998
July	-3635	-4670	-17341	9966
Aug 1-15	-16468	-27213	-13610	-9903
Aug 16-31	-2092	2419	6740	-24269

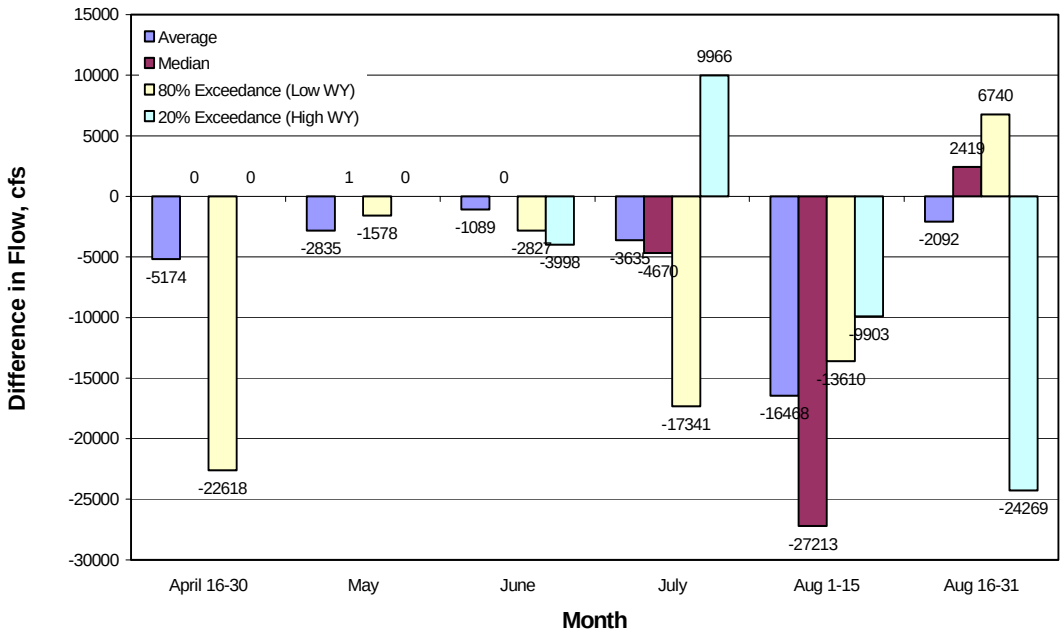

Figure 3. Monthly and bi-monthly differences in discharge at McNary that could be expected for varying water years if the NWPPC preferred alternative were implemented, differences are relative to the current Biological Opinion operations. Negative values indicate less discharge would occur under the NWPPC Plan, positive values indicate greater discharge would occur under the NWPPC Plan, and zero values indicate no change in discharge would be expected.

Table 6 and Figure 4 display the month-to-month differences in discharge at McNary that could be expected during varying water years if the NWPPC Plan were implemented, relative to pre-water budget operations. Month-to-month discharges at McNary resulting from the NWPPC Plan would be increased over all periods *except* from April 16-30, relative to pre-water budget operations. During the average, median, and low water years discharges would decrease between 9,376 and 3,144 cfs relative to the pre-water budget period. This suggests that the NWPPC Plan would lead to a decay in April 16-30 flows, beyond that of the pre-water budget years.

Table 6. Monthly and bi-monthly differences in discharge at McNary that could be expected for varying water years if the NWPPC preferred alternative were implemented, differences are relative to the current pre-water budget operations.

Date	Average WY Discharge (cfs)	Median WY Discharge (cfs)	80% Exceedence (Low WY) Discharge (cfs)	20% Exceedence (High WY) Discharge (cfs)
April 16-30	-9030	-9376	-3144	401
May	15097	33594	47759	-8933
June	13618	4168	47744	-1846
July	32872	47662	14906	54829
Aug 1-15	20358	17495	18539	18216
Aug 16-31	31013	26775	36163	28819

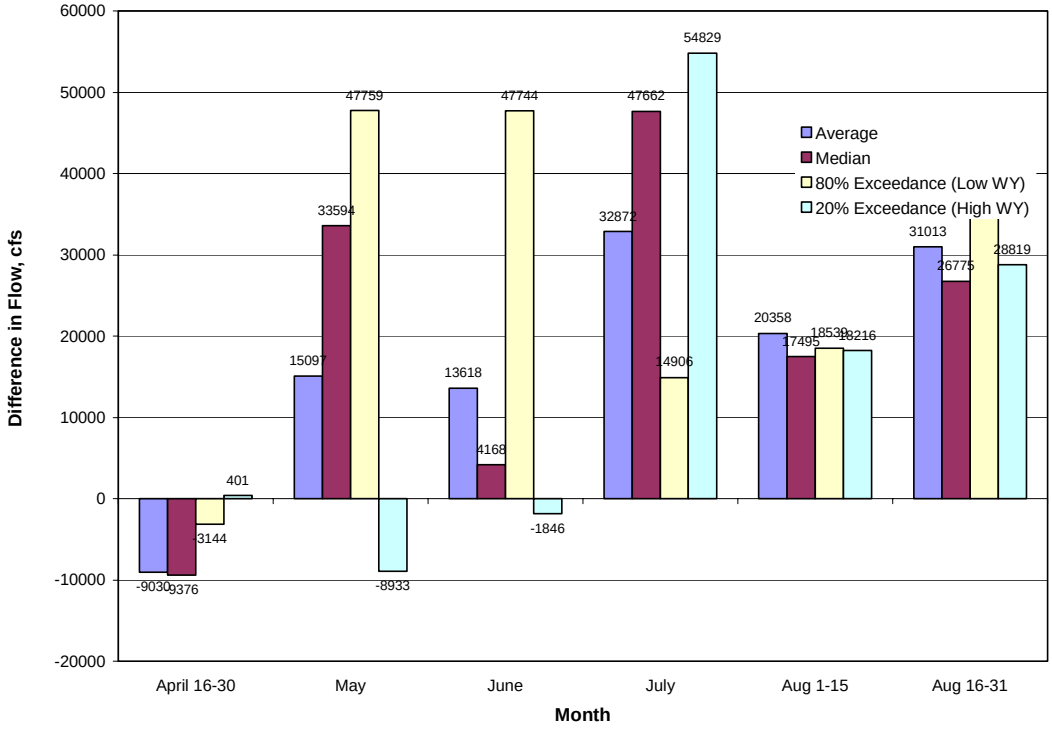

Figure 4. Monthly and bi-monthly differences in discharge at Lower Granite that could be expected for varying water years if the NWPPC preferred alternative were implemented, differences are relative to the current pre-water budget operations. Negative values indicate less discharge would occur under the NWPPC Plan, positive values indicate greater discharge would occur under the NWPPC Plan, and zero values indicate no change in discharge would be expected.

Table 7 displays the month-to-month differences in discharge at McNary that could be expected during varying water years if the NWPPC Plan were implemented, relative to the operation of the Columbia hydrosystem under the Biological Opinion operations, as presented by BPA. BPA modeling predicted that discharges would be influenced largely at McNary as a result of the implementation of the NWPPC operational plan. According to BPA model results, during low water years the second one-half of April could experience discharges 63,500 cfs less if the NWPPC Plan were implemented as compared to the BiOp. Also, during low water years, discharges are predicted by BPA to be between 4,500 and 12,900 cfs less between May and July if the NWPPC plan is instituted. Additionally, BPA results indicate that during average water years monthly discharges could be expected to drop between 2,900 and 24,300 cfs between April 16th and the end of July, again with the most significant drop in discharge in the second half of April.

In contrast to NWPPC models, BPA results indicate that discharges in the second one-half of April and the entire month of May will suffer the most severely. The NWPPC models predicted the largest drop in discharges in July and August. Both models agree that severe decreases in discharges can be expected at McNary Dam if the NWPPC Mainstem Amendment is implemented.

Table 7. Monthly and bi-monthly differences in discharge at McNary that could be expected for varying water years if the NWPPC preferred alternative were implemented, differences are relative to the hydrosystem under Biological Opinion operations. Analyses presented by the Bonneville Power Administration.

Date	**Average WY Discharge (cfs)**	**Median WY,** 1967 (The Dalles) **Discharge (cfs)**	**80% Exceedence** (Low WY, 1939 The Dalles) **Discharge (cfs)**	**20% Exceedence** (High WY, 1957 The Dalles) **Discharge (cfs)**
April 16-30	-24300	-8800	-63500	-62800
May	-5200	-100	-12900	-3400
June	-2900	2500	-4500	-8500
July	-5500	-2800	-9700	-10900
Aug 1-15	2100	1600	9900	0
Aug 16-31	2200	13500	1500	700

Additional calculations were performed which converted the differences in instantaneous discharge between the NWPPC Plan and the Biological Opinion to volumes over the respective month or bi-month periods. For example, during an average water year from April 16-30 at Lower Granite the difference in instantaneous discharge was calculated to be –316 cfs (Table 2), which multiplied by 86400 seconds in a day and 15 days (between April 16-30), is equivalent to 409,536,000 cubic feet or 9.4 Kaf. Therefore, it could be assumed that if the NWPPC Plan were instituted, 9.4 Kaf less water (relative to the BiOp) would be available over the second part of April. Table 8 summarizes monthly volumes of water lost or gained as a result of the NWPPC Plan, relative to the BiOp.

Table 8. Monthly and bi-monthly volumes of water lost or gained at Lower Granite as a result of implementation of the NWPPC preferred alternative, differences are relative to the 2000 Biological Opinion operations. Negative values indicate a loss of water, positive values a gain of water.

Date	Average WY Volume (Kaf)	Median WY Volume (Kaf)	80% Exceedence (Low WY) Volume (Kaf)	20% Exceedence (High WY) Volume (Kaf)
April 16-30	-9.4	-2.1	0.0	0.0
May	-12.6	0.0.	0.0	0.0
June	-11.8	0.0	0.0	0.0
July	-93.8	-163.1	-442.7	288.5
Aug 1-15	-19.8	-13.9	-30.3	-11.7
Aug 16-31	69.2	-6.4	208.9	-18.1
Volume Lost/Gained				
April 16 to June 30	-33.8	-2.1	0.0	0.0
July 1 to Aug 15	-113.6	-177.0	-473.1	276.8
April 16 to Aug 31	-78.1	-185.5	-264.2	258.7

From Table 8, during average, median, and low water years at LGR, the NWPPC Plan would shift 113.6, 177.0, and 473.1 Kaf of water out of the time period between July 1 and August 15 (according to NWPPC results).

Table 9. Monthly and bi-monthly volumes of water lost or gained at McNary as a result of implementation of the NWPPC preferred alternative, differences are relative to the 2000 Biological Opinion operations. Negative values indicate a loss of water, positive values a gain of water

Date	Average WY Volume (Kaf)	Median WY Volume (Kaf)	80% Exceedence (Low WY) Volume (Kaf)	20% Exceedence (High WY) Volume (Kaf)
April 16-30	-153.7	0.0	-671.8	0.0
May	-174.0	0.1	-96.9	0.0
June	-64.7	0.0	-167.9	-237.5
July	-223.1	-286.6	-1064.4	611.7
Aug 1-15	-489.1	-808.2	-404.2	-294.1
Aug 16-31	-66.3	76.6	213.5	-768.8
Volume Lost/Gained				
April 16 to June 30	-392.4	0.1	-936.5	-237.5
July 1 to Aug 15	-712.2	-1094.9	-1468.6	317.6
April 16 to Aug 31	-1170.9	1018.2	-2191.6	-688.7

From Table 9, during average, and low water years at McNary Dam, the NWPPC Plan would shift 392.4 and 936.5 Kaf of water out of the time period between April 16 and June 30th (according to NWPPC results). Additionally, during average, median, and low water years at McNary, the NWPPC Plan would shift 712.2, 1094.9, and 1468.6 Kaf of water out of the time period between July 1 and August 15. Overall, between April 16 and August 15, 1104.6 Kaf of water would be lost during average water years and 2405.1 Kaf would be lost during low water years.

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The Impacts of Alternative Management Plans on Snake River Spring Chinook

By

Earl Weber
Columbia River Inter-Tribal Fish Commission

February 2003

Introduction

As part of its amendment process, the Northwest Power Planning Council (NPPC) is considering river operations for the FCRPS that differ from those described by the National Marine Fisheries Service (now NOAA Fisheries) in its Biological Opinion for the Federal Columbia River Power System (BIOP). The Treaty Tribes have also recommended an interim plan for river operations. The purpose of this paper is to assess the impacts of all three plans on one affected fish stock, Marsh Creek spring chinook. Marsh Creek is a tributary of the Snake River in Idaho.

Methods

Like past assessments, this one uses both a passage model and a lifecycle model. The passage model (Spring Chinook FLUSH version 2003 aka SPF3) has been calibrated using only PIT Tag survival data. Details appear in Appendix A. Input to the model are 50-year flow and spill files output from the hydrosimulation model GENESIS. Thus the survival of the fish under each management scenario is based on entirely on the hydrosimulation files with the same 50-year sequence to minimize inconsistencies due to data differences (apples and oranges). Four scenarios were assessed: NPPC, Tribal and BIOP, the latter assumed to being representative of baseline conditions. The 50-year mean of the management scenarios, relative to the BIOP scenario, are the input as Incremental Factors (IFs) to the lifecycle model. The fourth scenario was a breaching scenario that is called for in the Tribal plan.

Recent analyses have indicated that there are differences in survival between Snake River spring chinook and their lower river counterparts beyond that explained by direct hydrosystem mortality alone (Deriso 2001, Schaller et al. 1999). Dubbed differential or delayed mortality, it appears to exceed levels of direct mortality. Accordingly, for the Tribal proposal and the breaching scenario, increases in direct survival, relative to the baseline (BIOP), are accorded a proportionate reduction in delayed mortality. This is because delayed mortality appears to increase under conditions of low flow and spill (Appendix B). Note that the BIOP (baseline) and

NPPC plans are not accorded reductions in delayed mortality because they do not represent departures from hydro operations of the 1980's and 1990's, the era in which delayed mortality estimates were made.

The lifecycle model is a Variable Slope Stock Recruitment model or VSSR (Weber, in prep[1]). A description appears in Appendix C. Briefly, this model uses historic stock recruitment data for Marsh Creek to define the potential of the stock (the dome in a Ricker type model.) In this model, the slope of the stock recruitment curve is attenuated so as to pass through recent stock recruitment data points in a calibration procedure. Unlike most stock recruitment models, assumed increases due to management plans (the IFs) act on the model by increasing the slope of the stock recruitment curve instead of increasing the number of spawners. The initial population of the model was formed (seeded) using the most recent five years of spawners from the Marsh Creek stock (1997 – 2002). Simulations for all four scenarios consisted of the average of 100 games of 60 years each. The model was seeded with the most recent 5 years of spawners for Marsh Creek. To the extent other H's affect Marsh Creek, no change is assumed.

The VSSR does not produce optimistic results when assessing stocks such as Mars Creek that are below replacement, a criticism of other stock recruitment models. Because the Marsh Creek is operating below replacement, even after the IFs have been invoked, the chosen output of VSSR is time to extinction rather the probability of meeting a survival or recovery goals. Extinction (actually quasi extinction) is defined as the point where the population falls below 75 fish per generation (15 fish per year). The exception to this was the breaching scenario in which the IF brought the slope of the curve above replacement. For the breaching scenario the output was the probability of doubling the population in 25 years (i.e. e. twice the average of the 1997 – 2002 Marsh Creek spawners).

Results

Results of passage model (SPF3) simulations, run with 50 year flow and spill files output from hydrosimulation model for the BIOP (baseline) Tribal and NPPC proposed plans are shown in Figure 1.

[1] Accepted for review Can Jour. Fish Aquat Sci. Jan. 2003

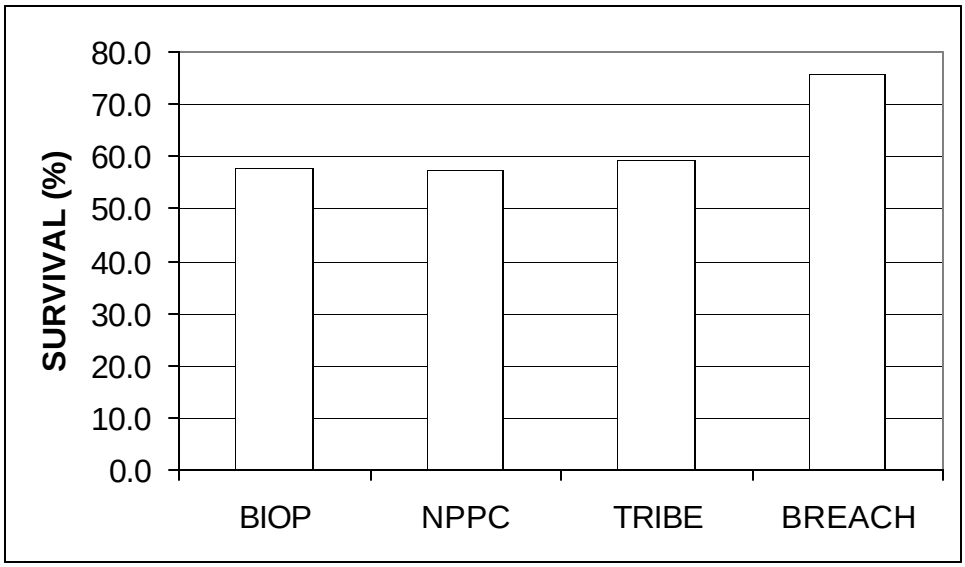

Figure 1. The mean direct system survival for three management proposals.

When the reductions in delayed mortality are combined with increases in direct survival for the Tribal plan and the breach scenario, the resultant incremental factors (IFs) are as shown below.

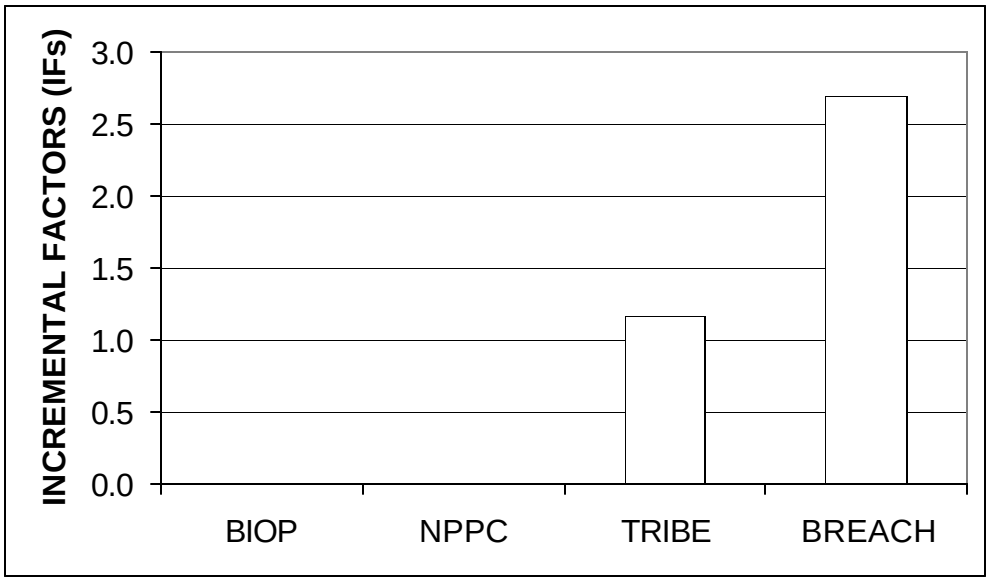

Figure 2. The incremental factors (IFs) including increases in direct survival and decreases in delayed mortality. IFs are the input to the VSSR lifecycle model.

The potential for increasing survival through the reduction of delayed mortality are well illustrated in Figure 2. This topic is discussed in Appendix B.

The changes in survival relative to the BIOP (IFs) were used to modify the slope of the VSSR lifecycle model. The time to (quasi) extinction was determined for the three Flow/Spill plans (Figure 3).

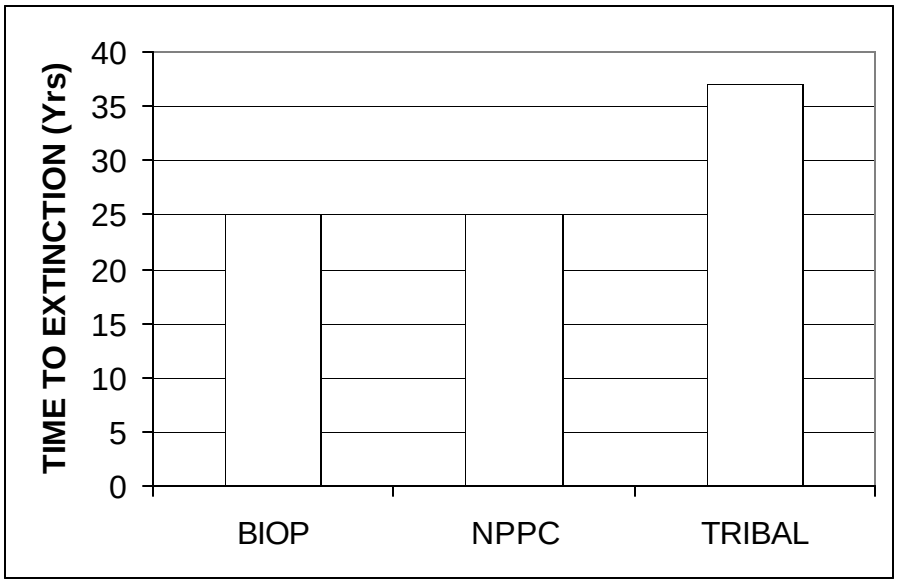

Figure 3. Time to quasi extinction for three flow/spill proposals.

The Tribal proposal should not be viewed as a long-term proposal. Rather, it is intended as an interim plan intended to buy time; an estimated 12 years above and beyond the plans of the BIOP and NPPC plans.

On the other hand, the breaching of the four Snake River dams has been proposed by the Tribes as a long-term recovery plan. The probability of doubling the population, a Power Council goal, was calculated for two conditions, immediate breaching and a five-year delay (Figure 4).

Figure 4. The probability of achieving the goal of doubling the stock in 25 years.

By breaching the four Snake River dams immediately, the probability of doubling the stock from the current average (1997 – 2002 average is 135; goal is 270) is estimated to be 99 percent. A five-year delay diminishes the probability to 83 percent.

Discussion

None of the flow/spill proposals analyzed ensures the long-term existence of Snake River spring chinook. The Tribal plan is considered to be an interim plan intended to buy time, not recover Snake River spring chinook.

The relative differences in time to extinction are stressed over the absolute times presented above. As new data are gathered the absolute times may change somewhat. For example, recent increases in spawner escapements increased starting point for VSSR simulations and thus increased the time to extinction. Note, however, that despite a few good returns in the 1990's the average (actually the geomean) recruit per spawner values decreased substantially relative to the 1980's. This analysis used recruit per spawner data from the 1980's and 1990's to benefit from a longer data set. But if the recruit per spawner values of late are part of a trend, the times to extinction will be considerably shorter than those indicated in this analysis.

Breaching the four Snake River dams was the only option under which the stock being analyzed did not become (quasi) extinct within a relatively short time. In both cases assessed (immediate and five year delay), there was a high probability of doubling within 25 years.

Appendix A
Spring Chinook FLUSH version 2003 (SPF3) Documentation
By
Earl Weber

The FLUSH (Fish Leaving Under Various Hypotheses) model was rewritten in early 2003 and differs from previous versions in several ways. First, survival estimates are based only on PIT tag data for migration years 1994 through 2002. A second difference between this and previous versions is that this model indexes flow through water travel time rather than fish travel time. The relationship between system survival and water travel time is shown in Figure 1.

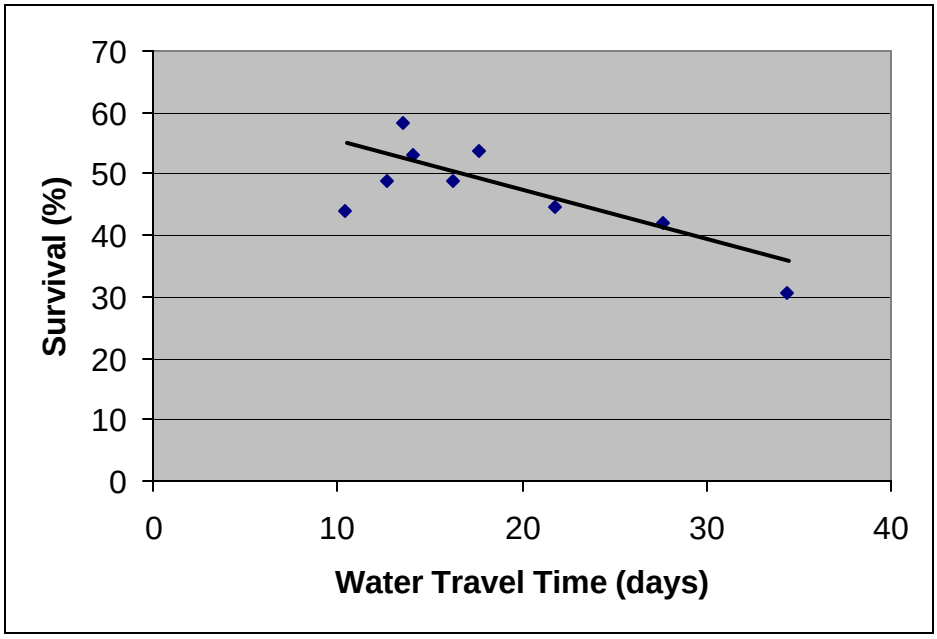

Figure 1. The relationship between the system survival of Snake River spring chinook and water travel time through eight reservoirs in the Snake and Columbia River.

With this data set there is a pronounced flow (water travel time) survival relationship but it is less pronounced that that exhibited by the older freeze brand data. The poorest survival (30%) occurred in 2001, a poor flow year.

Like previous versions of the model, the principle functional relationship is that between water travel time and reservoir survival rather than system survival shown above. Annual reservoir survival is found by determining the dam mortality at each project and backing out total dam survival from the system survival for each migration year. What is left over is reservoir survival for that year. This calibration occurred in spreadsheet SANDOCAL2003.XLS, which is available upon, request. The relationship between water travel time and reservoir survival is shown in Figure 2.

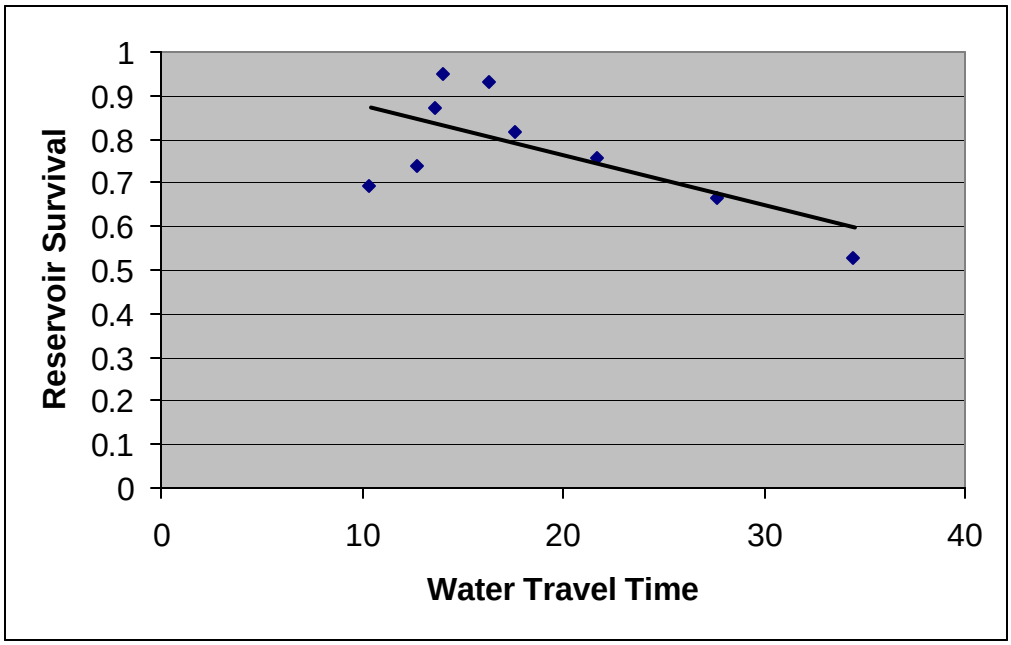

Figure 2. The relationship between the reservoir survival of Snake River spring chinook and water travel time through eight reservoirs in the Snake and Columbia River.

Total reservoir survival was allocated among individual reservoirs on the basis of water travel time.

SPF3 utilized a simple transport model. For the BIOP and NPPC analyses, flows below 100 KCFS resulted in transport at the upper three dams. Above that flow level there was no transportation. For the tribal plan there was no transportation in any situation. The level of "D" used to find system survival was set at 0.60.

Appendix B

Estimated Total Hydropower Mortality Using Adult Data

By
Earl Weber
CRITFC

Introduction

Between 1938 and 1975, eight dams were built that separated spawning areas for Snake River salmonids from the Pacific Ocean. Dam construction was accompanied by decreased survival among all Snake River salmon stocks. In the 1960's researchers began to conduct mark and recapture studies to estimate survival through various reaches in the mainstem hydropower system and, although the methodology has changed through time, these studies have continued to the present time. However, these types of studies do not estimate the extent of delayed mortality due to stress and injury as a result of passage through the hydropower system.

In 1996, regional scientists began a collaborative process aimed at evaluating management alternatives for recovering Snake River salmon stocks listed under the Endangered Species Act. The process, known as PATH (Plan for Analyzing and Testing Hypotheses) involved the development of an analytical framework to aid analysis and decision making. The modeling framework consisted of a retrospective model that was used to analyze existing data and estimate parameters, and a prospective model used for forward simulations.

The retrospective model was a modified Ricker model (Ricker 1975) that simultaneously estimated the 'a' and 'B' parameters for two groups of stocks: those above all eight dams on the Snake River and those farther downstream that acted as control or comparison stocks. Two additional parameters were added to the basic Ricker model. The first, delta, represented common year effects or the degree to which all stocks varied together among years. The second parameter, m, estimated the differential mortality between the two groups of stocks after common year effects have been taken into account. All stocks were spring/summer chinook.

The parameter m is interesting because it provides an estimate of the potential total mortality attributable to the hydropower system. The word "total" refers to the fact that m reflects both juvenile and adult mortality of fish regardless of whether they migrated downstream in the river or were transported. The word "potential" is used to indicate that at least part of the differential mortality measured by m could have been due to something other than the hydropower system. However, an alternative explanation of why the Snake River stocks underwent steep declines as the hydropower system was being developed, and the downriver stocks did not, has not surfaced. Therefore, it is assumed herein that differential mortality is due to the hydropower system.

The purpose of this paper is to review the method used to estimate differential mortality and to present annual estimates of same. The management implications are discussed as well.

Differential Mortality

The model used to estimate differential mortality (m) has been described in Deriso et al. (2000). Annual estimates of differential mortality were provided in Deriso (2001) and are presented in Figure 1.

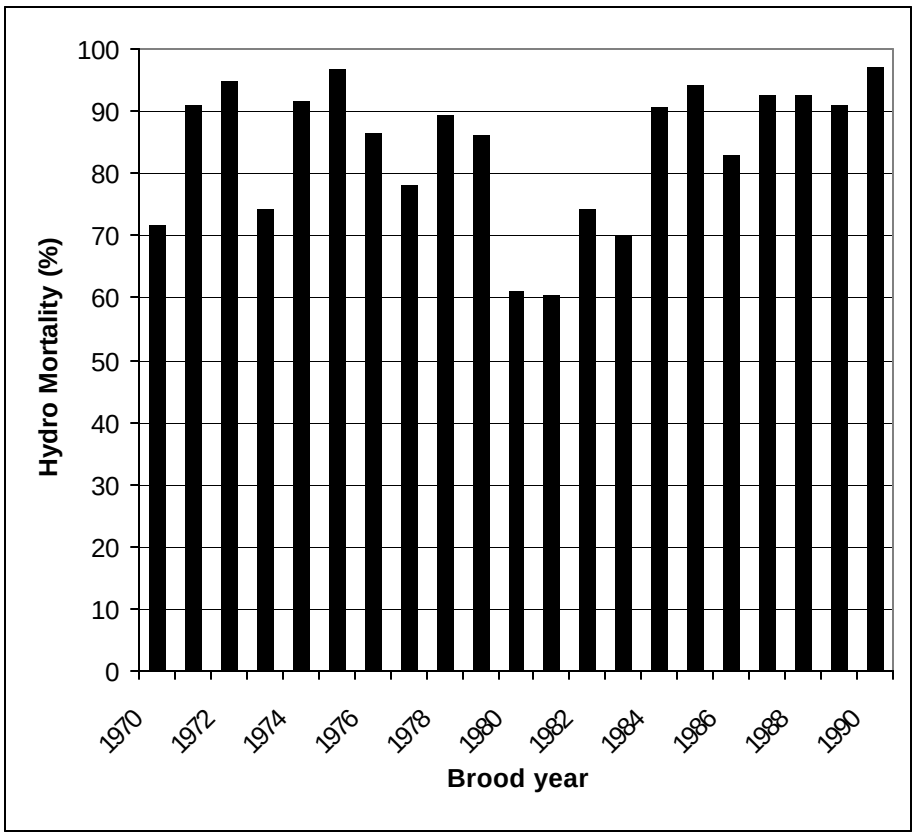

Figure 1. Total hydrosystem mortality estimates for brood years 1970 through 1990.

Total mortality varies considerably from year to year. The mean mortality for the data series is approximately 84 percent. The National Marine Fisheries Service (AKA NOAA Fisheries) has opined that migration conditions in the 1980s and 1990s were improvements over those of the 1970s, a period during which the hydrosystem was in a state of flux. There is some support for this theory because the affected brood years prior to 1980 (brood years 1970 through 1977) experienced a mean hydrosystem mortality of approximately 91 percent versus 83 percent since (brood years 1978 through 1990). This finding is clouded somewhat because the pre 1980 period contained two of the driest years on record whereas the later period contained some of the wettest years in recent history.

The relationship between survival of a brood and flow in the year affecting that brood (migration year is two years beyond brood year) is shown in Figure 2.

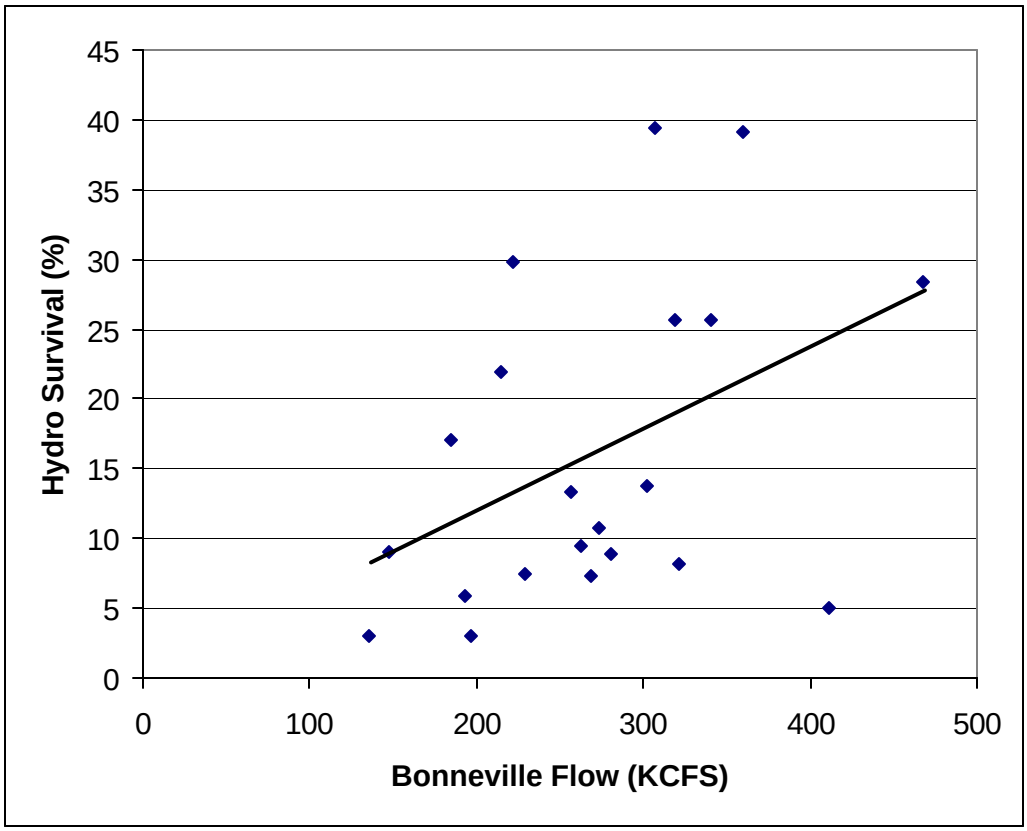

Figure 2. The relationship between total survival and flow for Snake River spring/summer chinook.

Assessing the Impacts of Delayed Mortality

The Power Council's amendment process has provided an opportunity to explore the potential impacts of reductions in delayed mortality. The Tribes have two proposals intended to improve survival of Snake River fish in general and spring chinook in particular. The first is an interim proposal for increased flow and spill volumes. The second is a breaching proposal. Both are intended to increase survival by providing more river-like passage conditions and, therefore, increase direct survival while reducing delayed mortality.

For both scenarios, increases in direct survival was matched by a proportionate reduction in delayed mortality. Thus the incremental factors (IFs) that drive the VSSR lifecycle model are a

product of both. A simple approach was chosen wherein projected increases in direct system survival are accompanied by proportionate decreases in delayed mortality. Mean Rather than year-specific values are used.

As noted already, the mean value for total mortality is approximately 83% or 17% total survival. Recent PIT tag data indicate inriver system survival is approximately 47%. Assuming 80% of the fish are transported and the post transport relative survival statistic, "D", is 0.6, system survival is assumed to be 57%. This is also the average SPF3 survival for both the BIOP and NPPC plans. The resultant "delayed survival" (i.e. 1 – delayed mortality) is 30%. The direct and delayed increases in survival (actually calculated as a decrease in mortality) for the Tribal flow/spill plan and the breaching scenario are shown in Figure 3.

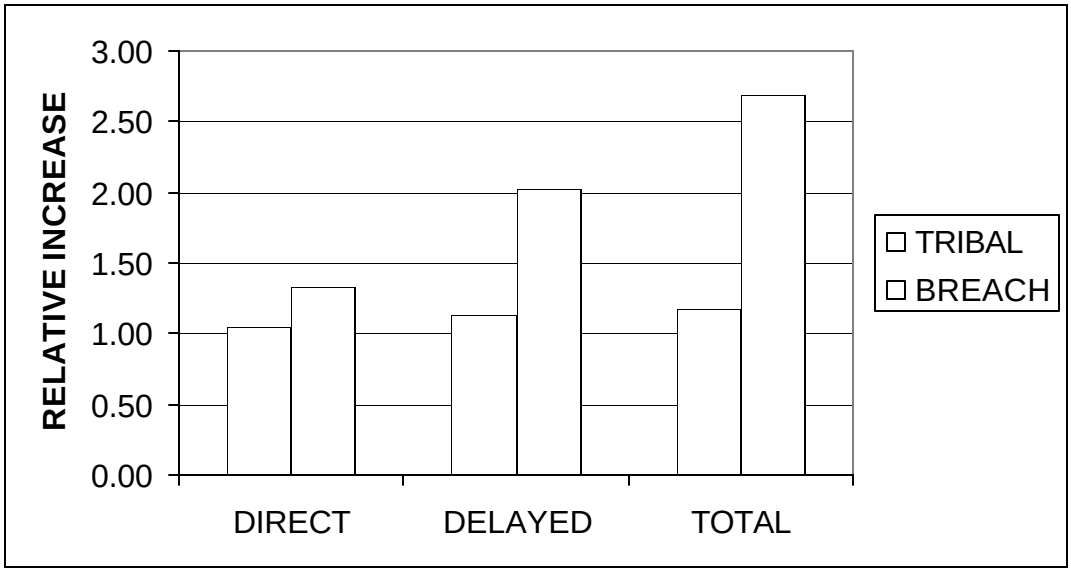

Figure 3. The relative increases in the direct and delayed survival associated with the Tribal flow/spill proposal and the breach scenario, and the totals.

Figure 3 illustrates the importance of delayed mortality in the recovery of Snake River spring chinook and possibly other stocks.

Management Implications

As noted previously, it is assumed that most, if not all, differential mortality is due to the hydropower system. A considerable amount of effort has been devoted to evaluating alternative hypotheses.
The intent here is not to repeat all the evidence linking differential mortality with the hydropower system. In brief summary, some Snake River spring/summer chinook stocks are in wilderness areas and are without hatchery influence. Their harvest rates have been reduced to the point where further reductions will not appreciably improve survival. In addition substantial

declines experienced by Snake River spring/summer chinook did not occur in the freshwater spawning and rearing phase (i.e. above Lower Granite Dam) but, rather, in the mainstem passage and Ocean phase (i.e. below Lower Granite Dam). While some have suggested that the source of this mortality might lie in the ocean phase, that would require that the Snake River spring/summer chinook stocks encounter some phenomenon that their downstream counterparts did not. This encounter would have to have occurred at the time of hydropower development but not be related to the many published stress and injury related to hydrosystem passage.

NMFS repeatedly acknowledges the injurious nature of mainstem passage in the Biological Opinion (BIOP; NMFS 2000) but did not take differential mortality into account when determining the allowable take for spring/summer chinook. the allowable take in the BIOP was 53 percent for juveniles and adults combined. Taking differential mortality into account, the allowable take should have ranged as high as 97 percent with a mean value of 83 percent as noted previously.

While NMFS has acknowledged that dam breaching offers the best hope for recovery, it has delayed moving in that direction opting, instead, to pursue other means of improving survival, most notably habitat improvement. In the near term, there are few measures at our disposal for increasing survival of Snake River spring/summer chinook. Because survival is highest in years with higher flow, and because these years are also associated with higher spill volumes, the Region should make every attempt to maximize flow and spill as interim measures

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Appendix C

A more dynamic, variable slope, stock recruitment function for addressing depensation and nonstationary data

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Abstract

Many fish stocks of interest to scientists are operating below replacement. Whether depensation is occuring in a biological sense is difficult to say but it is clearly occuring in a mathematical sense. Although stock recruitment models embody compensation rather than depensation, they are typically used in the assessment of depressed stocks. Techniques that deform stock recruitment curves to simulate depensation are of limited utility. Researchers interested in extinction risk use different types of models but those models don't have the dynamics of stock recruitment models and aren't well suited for making projections reflecting intended management actions. This paper proposes a more dynamic approach toward assessing stocks at risk of extinction and attempts to bridge the gap between stock recruitment models and extinction models. A variable slope Ricker model is described and discussed.

Introduction

Density dependence can be of either a compensatory or depensatory nature. Stock-recruitment functions in common usage (Ricker 1954; Beverton-Holt 1957) represent compensatory relationships in which, at low numbers, populations enjoy high replacement rates as represented by steep ascending limbs on the curves. Conversely, some scientists have argued that at low population numbers depensation occurs. First suggested by Allee (1949), it is often used to convey the risk to stocks from reduced genetic variability and demographic effects. Whether or not a stock is threatened by depensation is difficult to determine but, from a mathematical perspective, many stocks are experiencing replacement rates below one-to-one and are acting more as if depensation, not compensation, is acting upon them.

Data nonstationarity is one problem that often confronts those analyzing depressed stocks. The Plan for Analyzing and Testing Hypotheses (PATH; Marmorek et al. 1998) sought to analyze spring/summer chinook stocks in the Middle Fork of the Snake River in Idaho. These stocks are characterized by data nonstationarity as exemplified by one of the stocks, Marsh Creek (Figure 1.)

[Figure 1]

Recruit-per-spawner data for Marsh Creek represent three stanzas. Data from the 1950s and 1960s represent a period in which the stock was in healthy condition and was at or near full

seeding. During the 1970s the stock underwent steep declines as the result of hydropwer development and relatively high harvest rates. Since then (1980s and 1990s), the stock has remained at lower levels of abundance and has, on average, been below replacement (geomean of 0.63.) Note that Marsh Creek spring chinook became depressed due to density independent factors, unlike the situation described by Reisenbichler (1989), for example, in which recruit-per-spawner values declined due to a density dependent factor (habitat degradation).

PATH scientists were aware of the data nonstationarity, and recognized the optimistic nature of the Ricker model being used in that process, and instituted a potential solution in the form of a function that depressed the Ricker curve near the origin. The result was a depensation dent such as that depicted by Hilborn and Walters (1992) and Quinn and Deriso (1999). However, the curve quickly regained its upward trajectory beyond the dent, and model outcomes were not greatly affected. Model games in which extinction occurred were rare, particularly given that the stocks involved are below replacement.

As a result of this optimism, conservation biologists and others interested in assessing the risk of extinction have developed tools other than stock recruitment functions. Dennis et al. (1991) derived a model specifically for that purpose. A modified version of it has been used on Snake River salmon stocks (McClure et al. In press). Others (e.g. Cooney et al. 2001) have simply sampled from the recruit-per-spawner (or spawner-per-spawner) data to estimate the population trends for stocks of interest. However, extinction models are themselves optimistic when used for forecasting the effects of management actions because they lack the constraints of stock recruitment models.

The problem, then, is although both classes of models ultimately concern themselves with a given stocks replacability, neither provides seamless projections of stock productivity from scarcity to ubiquity. Stock recruitment models are in their element when stocks are well above replacement but produce optimistic results when stocks are below replacement. The opposite can be said of extinction type models.

This purpose of this paper is to describe one approach toward more dynamic stock recruitment function intended to bridge the gap between stock recruitment models and extinction type models. The approach involves a stock recruitment function in which the slope of a model varies to accommodate different states of a stocks health as determined by recruit per spawner data. Data that represent the stock under healthy conditions represent the potential of the stock. The slope of the model can be made shallower to represent the stock in a more depressed state such as a stock that is below replacement. The models's slope is increased through increases in recruit per spawner assumed to be associated with management actions.A modified Ricker model is use to describe the approach but other stock recruitment models are discussed also.

The Model

The Ricker type approach uses the standard Ricker function modified by a calibration factor, c, applied in two places:

$$R = caSe^{-cBS}$$

Where:

R is recruits

S is spawners

a is a fitted dimensionless parameter that determines the slope at the origin

B is a fitted parameter with dimensions 1/S, and

c is a calibration coefficient that modifies the slope of curve.

The original Ricker model has been described in detail by Ricker (1954, 1975) and elsewhere (eg. Hilborn and Walters 1992; Quinn and Deriso 1999).The effects of the added calibration factor, c, are shown in Figure 2.

[Figure 2]

Figure 2 illustrates a hypothetical population at three different times and in three different states of health. Where c = 1, the curve represents the healthy population with its recruit-per-spawner data having been fit to a Ricker curve. In this case, the calibration factor, c, of unity has no effect on the equation or curve. The a value (slope at zero) is two and the maximum population size (1/B; the "dome") is 500 spawners. When c is set to equal 0.5, the dome is at 1000 spawners. When c is set to equal 0.25 the dome is at 2000 spawners. This would represent a population in the poorest of the three conditions. Note that the calibration parameter, c, has no intrinsic biological significance. It is merely a mathemetically convenient way to deform the stock recruitment curve.

These curves do not represent three models but one model representing three eras with different replacement capabilities. Note that with this particular approach, as that capability declines, the dome shifts to the right giving the misleading impression that the stock can overcompensate with impunity. In reality, as the replacement capability declines high spawner abundance becomes increasingly unlikely. Only by increasing the replacement capability (slope) can spawner abundance increase and this moves the dome back to the left.

With many conventional models, assumed increases in survival due to proposed management actions are introduced by increasing the number of spawners by some Incremental Factor (the big IF). With the approach presented here, such increases manifest themselves through increases in the stocks replaceability represented by increasing the slope of the curve. The IFs typically come from separate models or expert opinion. Whatever their source, the IFs are essential because it is the infinitely variable nature of the slope that satisfies the "continuous" assumption of the model. in a nonstationary data environment.

Fitting the Model

For demonstration purposes, spring chinook run reconstruction data for Marsh Creek, a tributary of the Middle Fork of the Salmon River, Idaho, was fitted to the Ricker model using recruit-per-

spawner data compiled during the PATH process (Marmorek et al. (1998). Like most, if not all stocks in this region, the Marsh Creek spring chinook stock has been reduced in numbers and falls below replacement on average.

Because this approach assumes that the dynamics of a stock in different states of health will be different, it follows that data for different eras should be used to define the curve representing those eras. Thus, data for brood years 1957 through 1969 were used to fit the data to a Ricker curve using a log-linear regression (Ricker 1975). The resulting curve represents the stock at or near full seeding and is shown in Figure 3.

[Figure 3]

To generate a curve representing recent, unhealthy conditions, the model was calibrated to coincide with data for brood years 1980 through 1994. Calibration consists of the following steps:

1. Estimate the mean number of spawners for the time period.

2. Calculate the geomean of the recruits-per-spawner for that time period.

3. Find a value of c in eq. 1 such that the resultant curve produces the correct number of recruits in the vicinity of the mean number of spawners (eg. if the geomean is 1.0 and the mean number of spawners is 100, solve for a value of c that produces 100 recruits.) The deformed curve for Marsh Creek representing recent, current conditions is shown in Figure 4.

[Figure 4]

Because the geomean of recruits-per-spawner was 0.637 and the mean number of spawners was 140, c was varied so that the model projected 89 recruits. Note that if the historic (uncalibrated) model were used, 140 spawners would beget 465 recruits, more than a five fold increase over what the replacement rate would seem to support, and more than three times the number needed for replacement. This illustrates the optimistic nature of traditional methods when mathematical depensation is in play.

To develop a curve to represent the replacement ability of the stock under future conditions with assumed increased survival rates, the geomean of recruits-per-spawner representing recent conditions was multiplied by the assumed IF and the model was calibrated as before.The resultant increase in the stocks assumed replaceability is illustrated in Figure 5.

[Figure 5]

Stochastic Model

This paper does not purport to review various ways to stochasticise a Ricker function but the approach seems to present a unique challenge. Just as the curve should be continuous, so presumably should be the

variance structure. This does not necessarily mean that the variance has to be the same in each era, but the structure should be the same. If not, determining the variability for prospective simulations becomes rather speculative.

One often used approach toward a stochastic version of a Ricker equation is to jackknife or bootstrap the data to obtain distributions of Ricker a's and B's. To illustrate how variance might be handled in a stochastic version of the variable slope model, the historic (1957 through 1969) data were jackknifed. The highest and lowest resulting curves are shown in Figure 6.

[Figure 6]

The same variance structure can be imposed on the curve representing recent (1980 – 1993) data simply by employing the same value of c for the jackknifed curves (Ricker a's and B's) that was used to generate the deterministic curve. The assumption for this example is that the variance associated with the Ricker a's and B's for the historic era adequately represents that of other eras. The results are shown in Figure 7.

[Figure 7]

There are many ways to develop a variance structure. The point here is to suggest that to be theoretically holistic, the variance structure, like the curve, should be continuous.

Model Performance

The stochastic model was used to estimate time to extinction (Leigh, 1981) and to demonstrate how the model performs over a range of hypothetical increases in replaceability. In addition to sampling from among jackknifed Ricker a's and B's, the future projections divided the recruits into two age groups (ages four and five) that largely comprise the annual broods for the Marsh Creek stock. Splitting the brood into different outyears reflects the salmon survival strategy of returning over different ages (Botsford and Brittnacher, 1998). Rather than dividing the brood by the average proportion of four and five year olds, the proportion were drawn from historic distributions of ages. The time to extinction simulation consisted of 100 games of 50 years each using the model calibrated to represent recent conditions. The projected number of spawners was averaged over the 100 games. Finally, a five year running average of the resulting data points was calculated to acknowledge generation effects. Results are shown in Figure 8.

[Figure 8]

The point at which the population drops below an assumed quasi extinction level of 15 fish is considered extinction. That point was reached in outyear 18 in this analysis. These results indicate that the approach presented here is far considerably less optimistic under baseline (current) conditions than than would be the case with assessments conducted with traditional stock recruitment models.

The performance of the model under hypothetical increases in replaceability rates, ranging from none to four times, are shown in Figure 9.

[Figure 9]

The above graph shows the effect of changes in nothing but the slope (replaceability rate). Under both current conditions and an assumed increase of one and a half times, replaceability rates are less than one (0.637 and 0.955, respectively) and recruit-per-spawner data points migrate toward the origin. As the slope increases (two to four times current rates) the first order dynamics begin to appear to the point where overcompensation becomes apparent.

Discussion

Regardless of whether or not biological depensation is occuring, the replaceability rates of many stocks is inconsistent with the assumption of compensation. While there may be situations in which stocks with increasing numbers follow the steep upward curve associated with compensation, it is difficult to imagine a situation in which stocks in decline would slide back down the slope, model stochasticity notwithstanding. Instead such stocks seem to take a more direct route toward the origin.Thus a given stock recruitment curve, that is assumed to represent the average relationship between spawners and recruits, may lead to optimistic outcomes.

In many instances low replacement rates are due to causes such as harvest and hydropower that are largely, if not entirely, density independent. But regardless of whether or not these stocks are feeling the effects of biological depensation, they are certainly within the bounds of "mathematical depensation" .

This paper describes a more dynamic approach that retains the dynamics of the Ricker model but accommodates nonstationarity without sacrificing continuity. The approach may serve as a framework for assessing stocks across the entire range of abundance from scarcity to ubiquity. Modulating the slope of the curve has the potential to more closely track changes in a stock's replaceability. The model produces less optimistic outcomes at the low end of the spawner range when compared to traditional stock recruitment functions. Even at high densities this approach may be more conservative because if anything less than complete restoration is assumed, the slope of the ascending limb will probably be less than that of a traditional model fit to historic data.

As replaceability gradually increases, the model performs in a manner not unlike depictions of depensation dents discussed in Hilborn and Walters (1992) and Quinn and Deriso (1999). However, with this approach a population cannot climb the steep ascending limb of the curve. Instead the population climbs only a preordained, modulated curve defined by actual or contemplated replacement rates. It may be that the first order dynamics of traditional models are too limited to address depensation.

Like most assessment tools in common usage, this approach assumes that biological depensation, if acting on a stock, is not asserting itself to the point where the stock has fallen below some threshold where the capacity for recovery is substantially impaired or impossible (Quinn and Deriso 1999). Clearly if a stock is unable to replace itself long enough depensation forces will exert increasingly greater effects. But even without any help from biological depensation, mathematical depensation can lead to extinction quickly enough.

While no attempt was made to duplicate PATH some comparisons are noteworthy. The nature of the model would seem to portend that results of simulations based on recent (current) conditions would be far less optimistic that those produced by the Ricker model used in PATH. The fact that the stocks usually fail to replace themselves indicates the probability of survival, let alone recovery, at any of the presribed time horizons (24, 48 or 100 years), would be at or near zero. At higher presumed increases in

survival, and hence replaceability, results obtained using the approach described herein would likely be more consistent with those of PATH.

This paper describes but one approach toward assessing depressed stocks. Although the Ricker model is used here to illustrate this approach, there is the potential to employ this approach with other stock recruitment functions. For example, in cases where historical data are not available, but estimates of carrying capacity are, a modification of the von Bertalanfy growth curve (Quinn and Deriso 1991) might be used. There may also the potential to use the approach on catch - effort based models like that described by Schaefer (1957).

Other treatments of a Ricker type model may also be useful. For example, in the case described by Reisenbichler (1989) where a stock was depressed due to habitat degradation, overcompensation may occur at lower levels of abundance. Thus the dome may stay at the same level of spawners (1/B) or even shift to the left. A Ricker type model may still be appropriate in this situation, but the the Ricker B parameter should perhaps be left unmodified or even treated in a way that shifts the dome to the left. Conversely, if there were a substantial decrease in available habitat without a degradation in habitat quality, the B parameter might change and the a parameter might not.

The variance structure that one chooses to use should be the one that best represents the population in different stanzas of abundance. In this example the variance in the historic period was used but it could be argued that the current, depressed state, if not more representitive, is more critical to recovery. In practice it would seem prudent to look at model outcomes with variances from both stanzas employed. It is not difficult to imagine a variance structure that gradually shifts from one variance structure to the next as abundance changes. No matter how one looks at it, in a situation where data are nonstationary, the variance structure is bound to be interesting.

This approach is expensive in terms of degrees of freedom. At first, only the historic data are used to define the potential productivity. Then the data from the current period are used in calibration. The data from the middle period of transition were not used at all in this example. Hopefully the potential increase in accuracy justifies the decrease in precision.

In sum, more dynamic stock recruit models may provide more realistic outcomes across a range of abundance than traditional stock recruitment or extinction type models. It is doubtful that stocks that are either increasing or decreasing in abundance would follow the path of typical stock recruitment curves, stochasticity notwithstanding. At least in some situations, depensation dents used with stock recruitment models curb, but do not eliminate, the optimism associated with stock recruitment functions. Modulating the slope of stock recruitment functions may provide a means of addressing depensation that cannot be achieved through the first order dynamics of traditional stock recruitment functions. Establishing a variance structure requires some thought but that is true whenever data are nonstationary. Finally, this approach is costly with respect to degrees of freedom but, hopefully, worth the expense.

Acknowledgements

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List of Figures

Figure 1. High spawner abundance data from the 1950s and 1960s (A) define the stock recruitment curve. Data from the 1970s (B) represent a period of transition. Data from the 1980s and 1990s (C) represent the current status of the stock (Marsh Creek, Idaho).

Figure 2. The effects of the calibration factor c on single Ricker equation.

Figure 3. A Ricker model fitted to data for the Marsh Creek spring chinook stock, brood years 1954 through 1969, an era of full or near full seeding.

Figure 4. Curve A is from the uncalibrated Ricker model. Curve B is the model calibrated to fit the 1980 through 1993 brood year geomean of recruit-per-spawner data whose points are shown.

Figure 5. Stock recruitment relationship representing historic (1950s & 1960s) conditions, current (1980s & 1990s) conditions and future conditions assuming a fifty percent increase in replacement rate above current conditions. The stock is Marsh Creek spring chinook, Idaho.

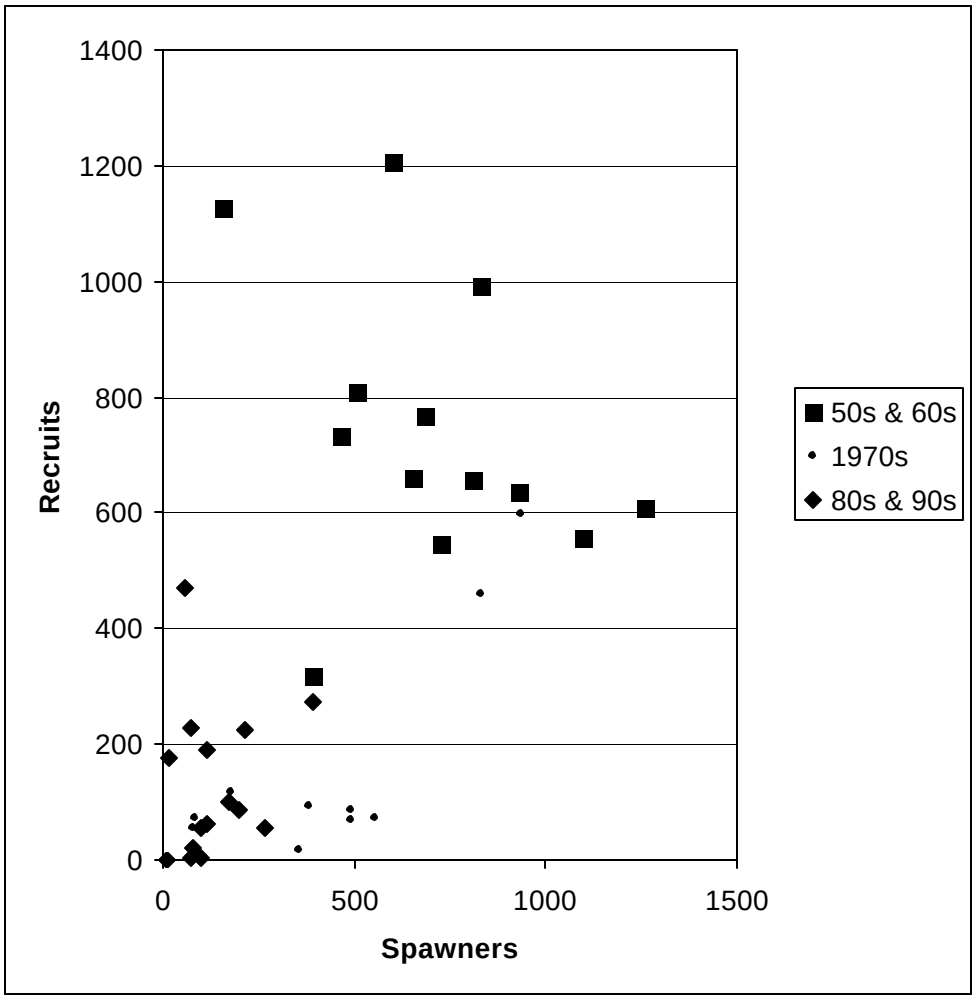
Figure 6. The highest (A) and lowest (C) curves resulting from jackknifing the historic (1957 – 1969) data for Marsh Creek, Idaho. Curve B is the fitted curve.

Figure 7. The error bounds imposed on curve representing current conditions, assuming that the variance structure generated for the historic era adequately represents current conditions. A is the highest bound and B is the lowest while B is the fitted curve.

Figure 8. The average time to extinction for Marsh Creek based on a simulation of 100 games. Each point is the running five year average of the average of 100 games.

Figure 9. One hundred year simulation projecting spawner and recruit values under four hypothetical levels of improvement: one and a half times, two times, three times and four time the replaceability rate for current conditions. Only the last twenty years of the simulations are shown. Under current condition stock has become extirpated and, therefore, no data points are shown

Figure 1.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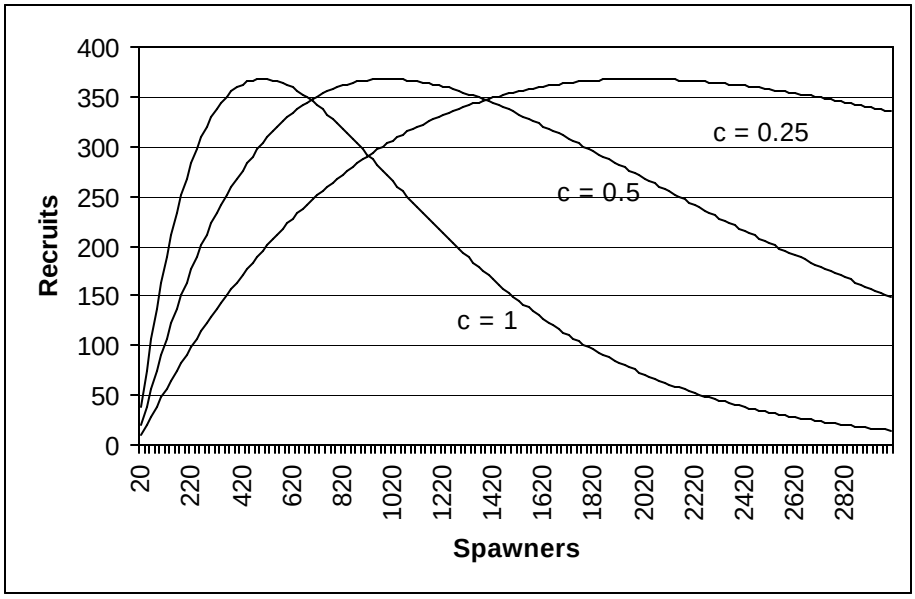
50s & 60s
1970s
80s & 90s

Figure 2.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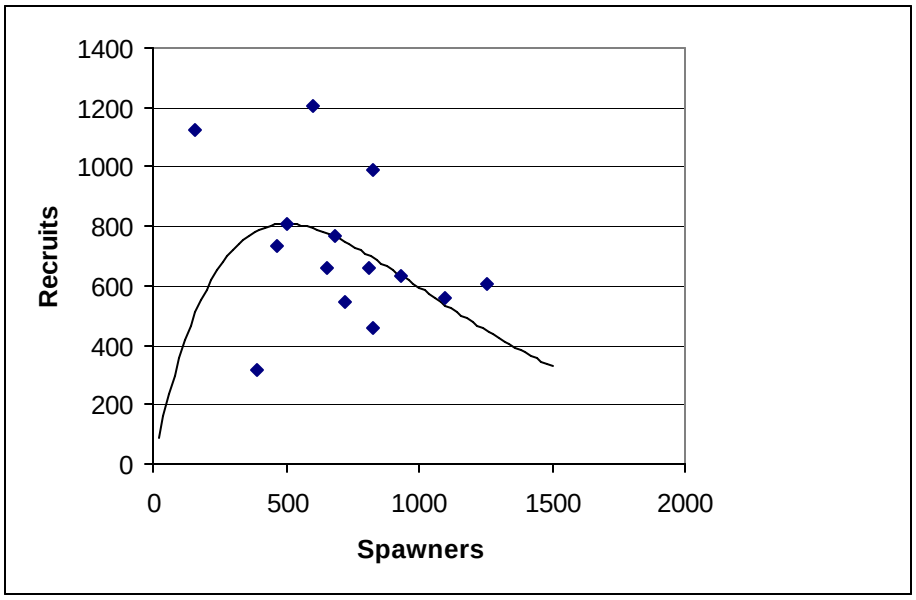
Spawners

Figure 3.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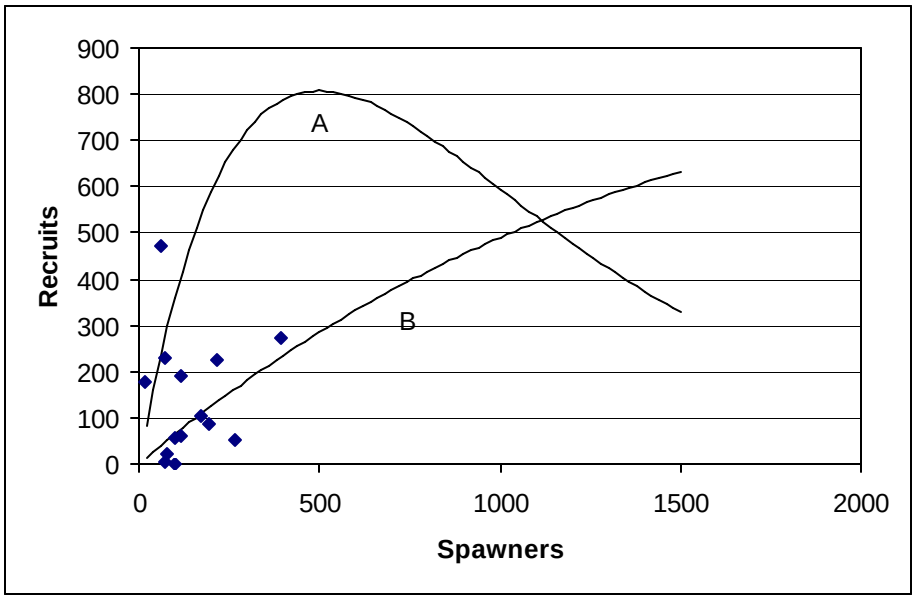
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Spawners

Figure 5.

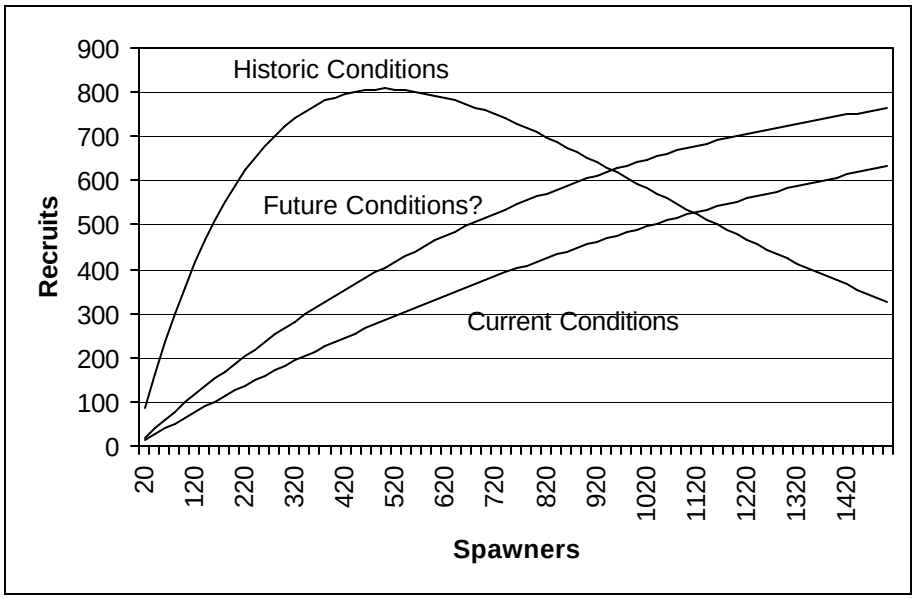
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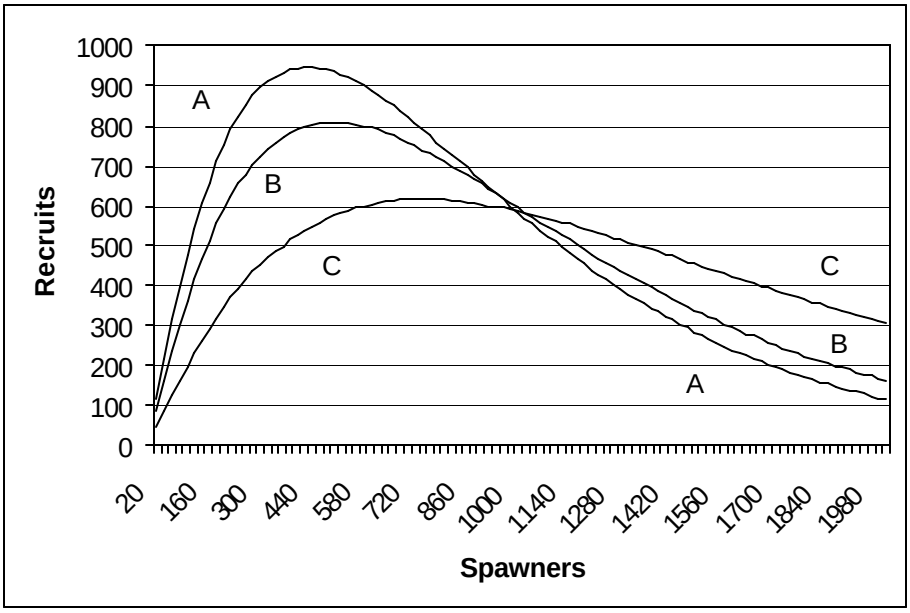
Figure 6.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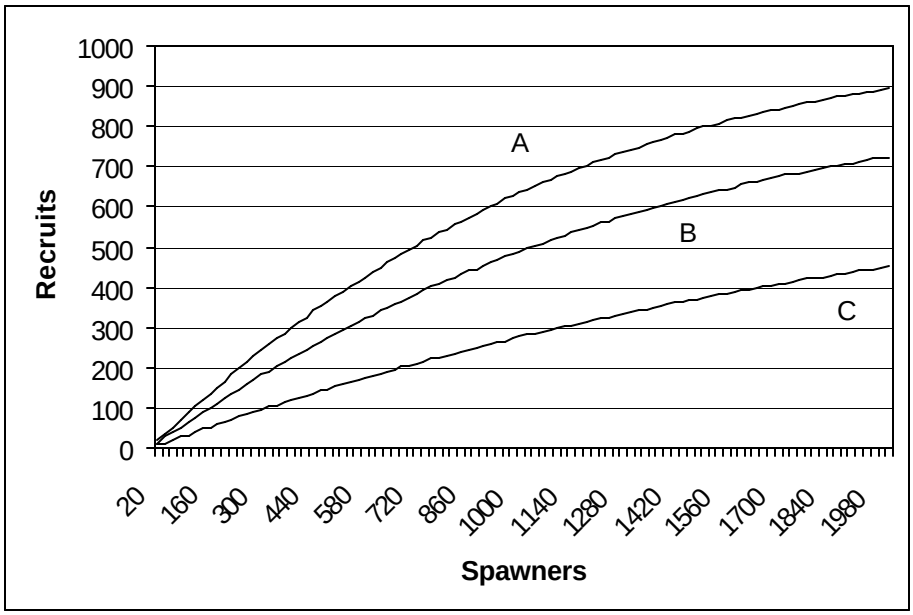
1700
1840
1980
Spawners

Figure 7.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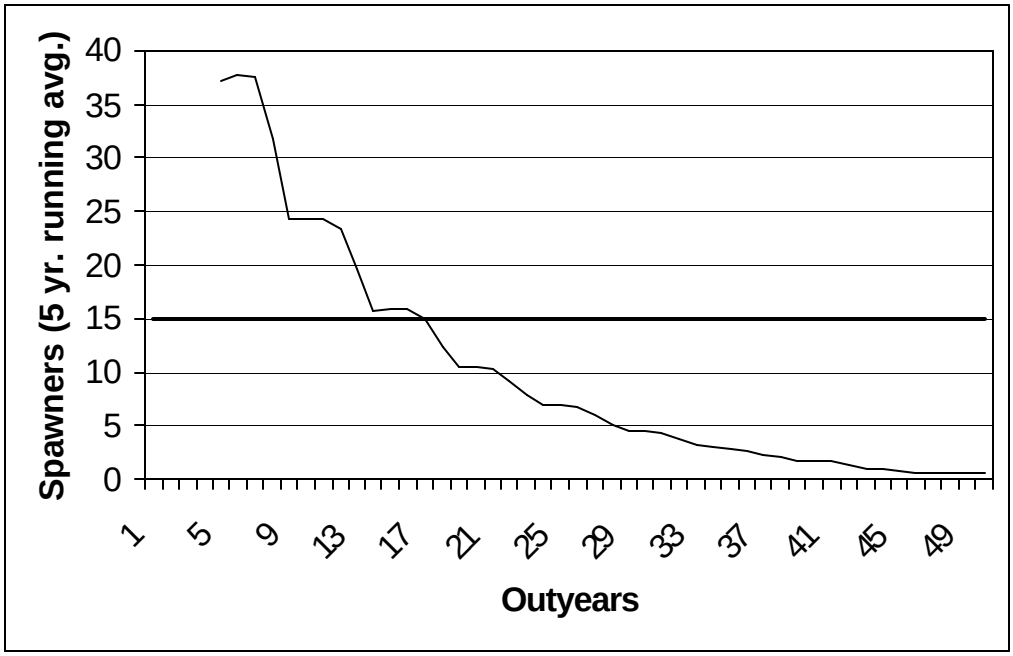
1840
1980
Spawners

Figure 8.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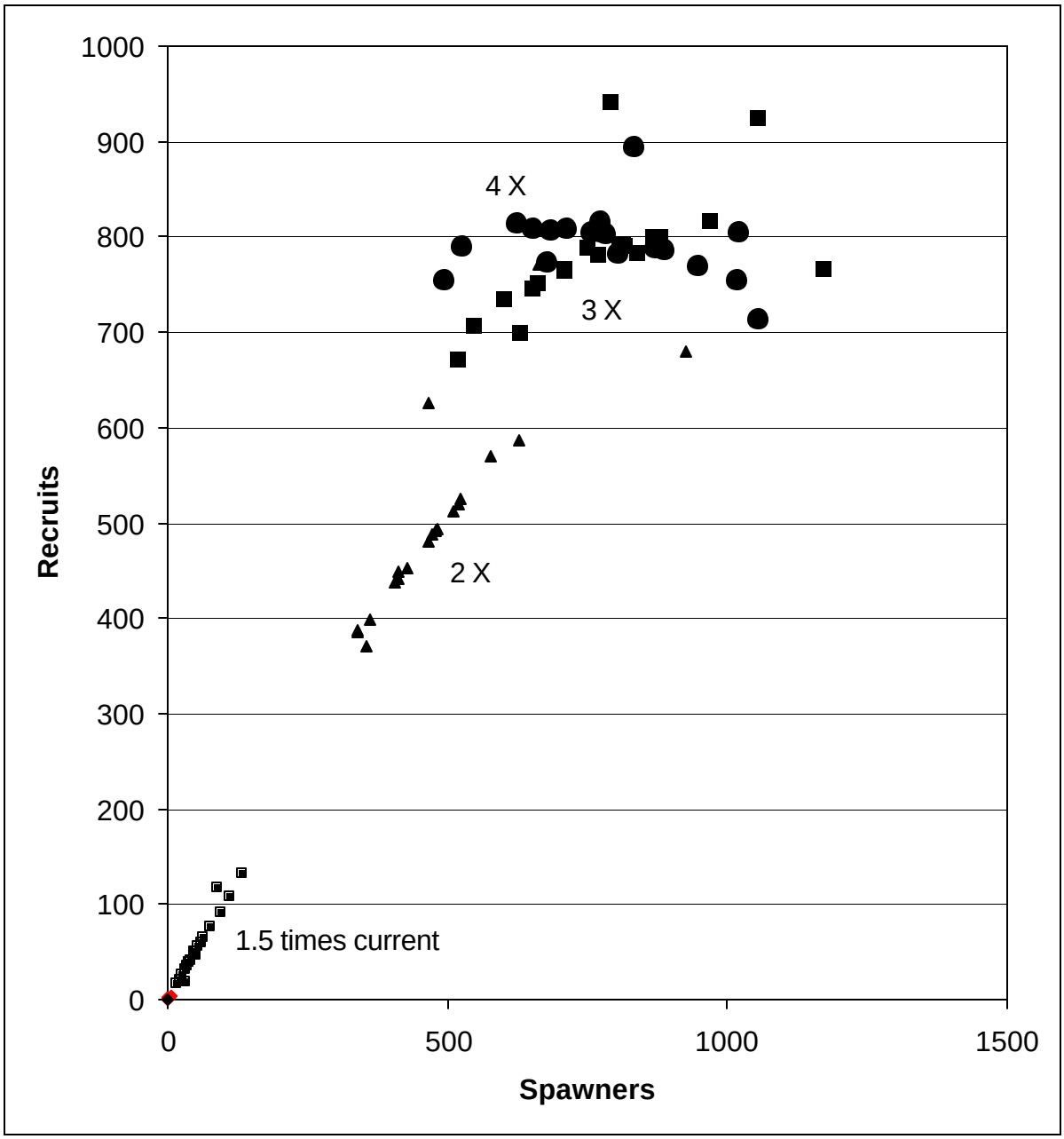
41
45
49
Outyears

Figure 9.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Recruits
4 X
3 X
2 X
1.5 times current
0
500
1000
1500
Spawners

COLUMBIA RIVER INTER-TRIBAL FISH COMMISSION
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Review of Amendment Proposals
before the Northwest Power Planning Council
Tom Lorz, Fish Passage Specialist
December 15, 2002

Overview:

Staff has reviewed the proposed system changes outlined in the Amendment process. Staff then used the SIMPAS model to evaluate the different operations. The flow and spill changes were lumped together for the analysis. The CRITFC river operation plan, and the current BiOp plan were also evaluated to use for a reference.

Modeling:

The SIMPAS model was employed primarily since council staff used it for there own analysis and have used it before in the past and are thus familiar with the model.

Once again the model has sever limitation that need to be addressed before hand. The model was designed to evaluate different project operations to determine which option produced the best outcome from a fish survival standpoint. However the model was extensivly modified during the writing of the 2000 BiOp to produce a system wide survival estimate for in-river and transported fish using generated pool survivals and "D" values. Staff generated specific comments regarding the SIMPAS in our comments to the 2000 BiOp. We attached those here. See Appendix 1.

Some of the main points generated in those comments were:

1. SIMPASS is not a flow sensitive model, and any flow changes will not be detected by it.
2. The pool survival estimates were generated during the 1995 –1999 time period. The average flow during this time period was above normal and therefore would likely generate a non-conservative estimate.
3. There is no time step, this is only a snap shot of survival for a given set of conditions, which could easily over or under estimate survival depending on the parameters used to represent this specific time.
4. There is no mechanism to deal with differential mortality due to passage route used; only a user supplied "D" value is available for the transported fish, and a reach survival estimated for below Bonneville.

Staff modified the way the model was run to help reduce some of these concerns. For the analysis only low flow and average flow years were evaluated. Spill was altered according to each plan, and pool survival was calculated based on a flow year basis as opposed to a per pool estimate.

Flow:

Staff used seasonal flow averages for the spring generated by employing the GENESYS model for each of the three scenarios; CRITFC proposed operation, BiOp operation and proposed Amendment for the NPPC.

Spill:

For the SIMPAS model, staff estimated the spill volume that would be needed to meet the targets of each plan. The NPPC amendment proposal stipulated spilling to a total dissolved gas level of 115% at the downstream fixed monitoring site. Information for this was limited, and staff had to estimate volumes of spill using past spill levels and corresponding TDG levels. Staff also referred to the spill levels used in the Council staff analysis.

Pool Survival Parameter:

Staff eliminated the pool survival parameter from the model since we do not view the methodology used in the model as appropriate to determine pool mortality. Instead we calculated a pool mortality parameter based on the type of flow year being evaluated. Using PIT tag survival data for 2002 and 2001 a system pool mortality was calculated. To do this SIMPAS was used to determine the sum of the project mortalities for each of those years. This was then subtracted from the Lower Granite Tailrace to Bonneville Tailrace PIT tag survival estimates for each of those years. With this we had a pool survival for average (2002) flow years and low (2001) flow years. Both of the years represent the best data for the current hydrosystem configuration.

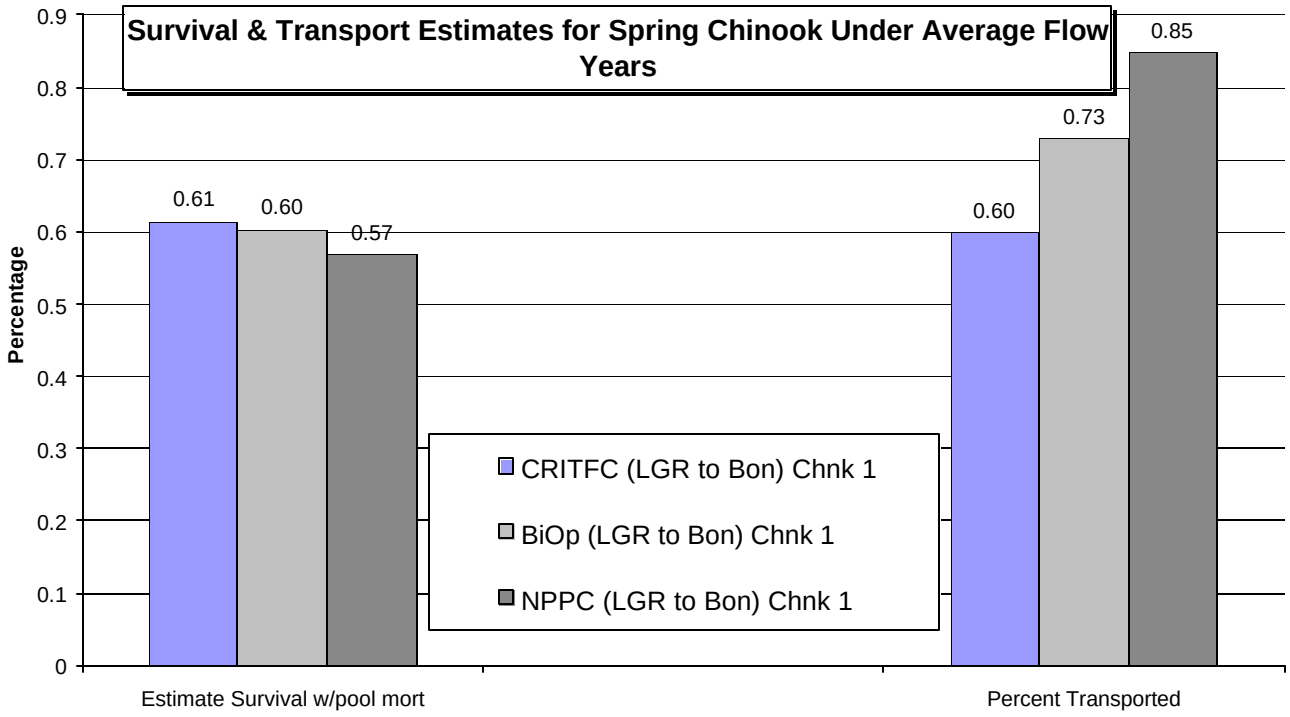
Results:

After completing the analysis the information was graphed to aid in understanding the information. (Refer to graphs 1-4) Staff added the percent of Snake River migrants transported to the analysis to determine what effects the different options would have on the transportation population. The transport percentages are not exact due to the technique used to calculate the system pool survival. The estimates are slightly inflated by ~2-3 percent, however the differences between the plans is accurate. The same can be said for the survival estimates, while the actual survival number is not exact, the relative differences among the alternatives are indicative of the likelihood of survival increases or decreases resulting from implementation of the identified measures.

The CRITFC plan provides the highest inriver survival and the lowest transport percentage. The BiOp has a similar inriver survival estimate but a much higher percent transported. The proposed Council amendment had the lowest inriver estimate as well as the highest transported percentage.

Current returns are calling into question the benefits of the transport program, especially at specific projects and during specific times of year. Thus it seems wise to adapt a more spread the risk policy and use transport sparingly and only to the parts of the run where a benefit has been demonstrated. Reviewing the results for the low flow conditions depicts a severe drop in survival of ~20% for both chinook and steelhead. Therefore it would seem prudent to operate the hydrosystem to reduce the possibility of encountering low flow like conditions. Furthermore, it would seem wise to verify these results with other more robust techniques that do a better job of taking into account flow/survival relationships as well as the per project mortality.

1)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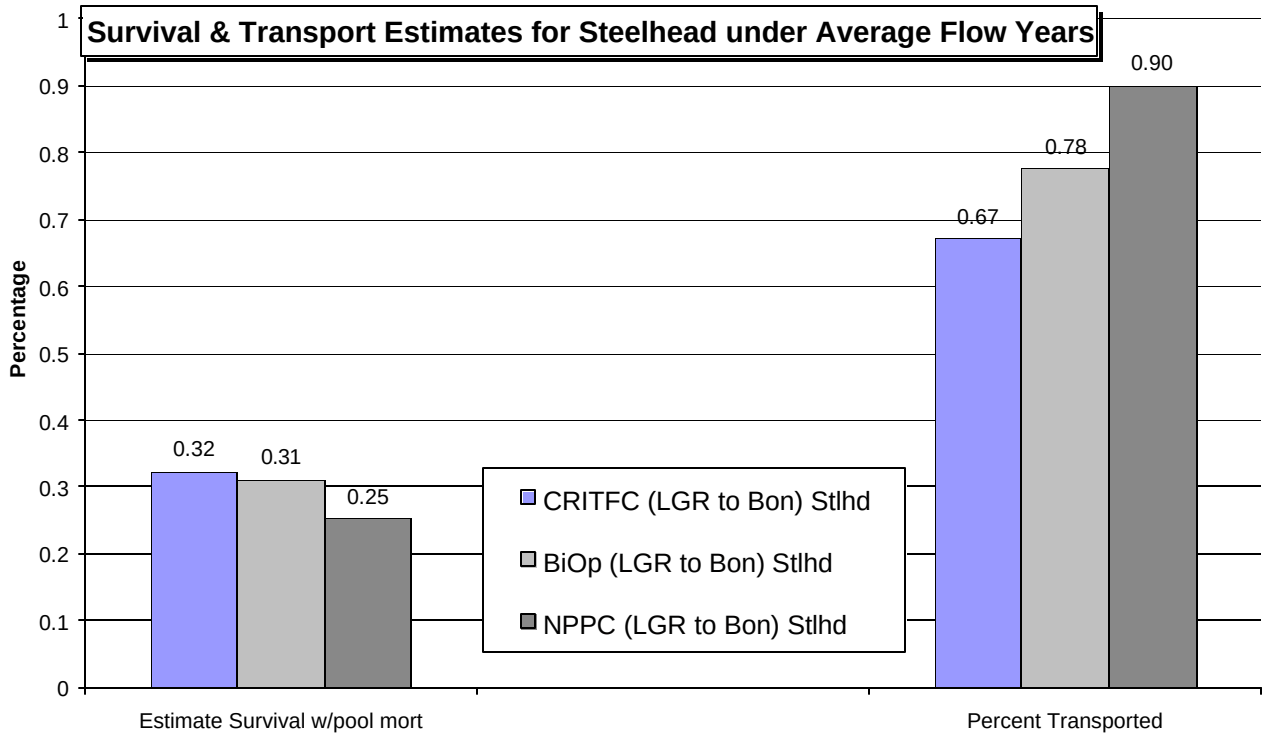
0.6
0.5
0.4
0.3
0.2
0.1
0
0.61
0.60
0.57
0.60
0.73
0.85
CRITFC (LGR to Bon) Chnk 1
BiOp (LGR to Bon) Chnk 1
NPPC (LGR to Bon) Chnk 1
Estimate Survival w/pool mort
Percent Transported

2)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0.8
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0.32
0.31
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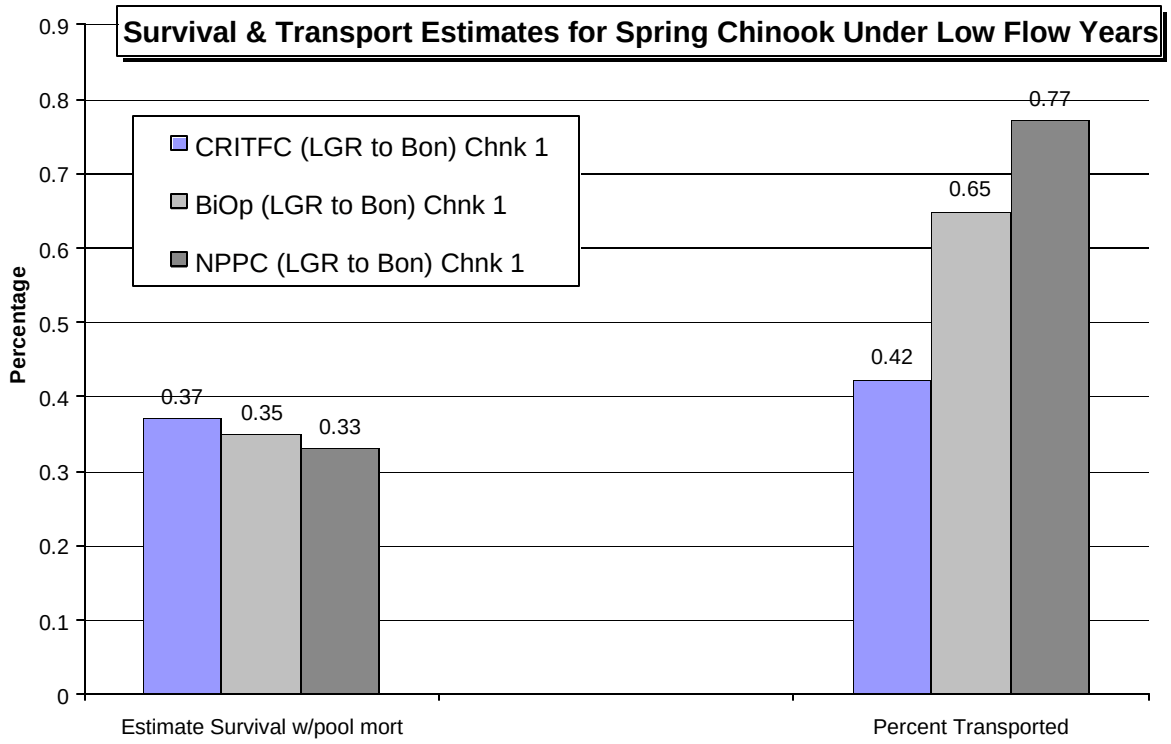
0.67
0.78
0.90
CRITFC (LGR to Bon) Stlhd
BiOp (LGR to Bon) Stlhd
NPPC (LGR to Bon) Stlhd
Estimate Survival w/pool mort
Percent Transported

3)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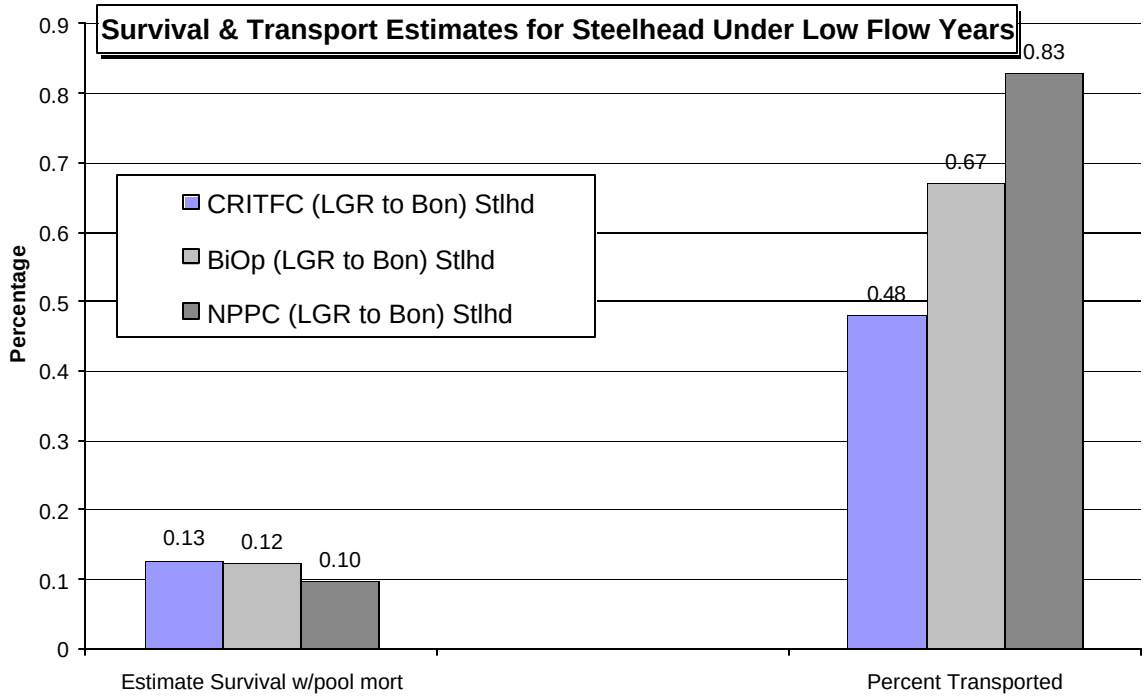
CRITFC (LGR to Bon) Chnk 1
BiOp (LGR to Bon) Chnk 1
NPPC (LGR to Bon) Chnk 1
Percentage
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.37
0.35
0.33
0.42
0.65
0.77
Estimate Survival w/pool mort
Percent Transported

4)


Survival & Transport Estimates for Steelhead Under Low Flow Years
CRITFC (LGR to Bon) Stlhd
BiOp (LGR to Bon) Stlhd
NPPC (LGR to Bon) Stlhd
Percentage
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.13
0.12
0.10
0.48
0.67
0.83
Estimate Survival w/pool mort
Percent Transported

Appendix 1

Comments on Appendix B
Biological Effects Team

SIMPAS Model:

The SIMPAS model is not an adequate model to analyze juvenile salmon project or reach survival through the FCRPS. It merely gives a point estimate, or snapshot of a survival estimate, based upon several fixed parameter assumptions. Further, SIMPAS does not address delayed mortality through the FCRPS, because it fails to incorporate a life history analysis. This differs from the PATH approach, which is supported by CRITFC and the member tribes. In addition, SIMPAS does not incorporate flow regulation and is insensitive to biological effects of flow management. We offer the following specific critique of SIMPAS:

- SIMPAS is not flow sensitive. The model does not differentiate between low and high flow years, weekly or daily average flows. There is no mechanism to account for changing flows on a daily or even weekly basis throughout the salmon migration season. The model only uses seasonal average flows and proportions this flow into individual passage routes at each particular dam. This approach disregards the flow-survival relationship, strongly supported by NMFS and regional reviews including PATH and Cada et al. (1994). Unlike FLUSH, there is no accounting for water quality impacts in the SIMPAS or in the cumulative effects of increasing temperatures to juveniles as they pass the project. SIMPAS attempts to account for this by using reach survival data gathered for each water year simulated. Reach survival data from Snake River studies is utilized and extrapolated for Columbia River reaches. This data is suspect because there is uncertainty in the study's ability to meet critical assumptions such as adequate mixing of forebay and tailrace replicates. For the Lower Columbia River and other reservoirs where there is no reach survival data, a reach survival estimate is derived from an extrapolation of the Snake River survival data to the length of the lower Columbia project reservoirs.

- SIMPAS is limited to flow data from 1994 to 1999. All of these years except 1994 were average to above average flow years. Year 1997 is one of the highest flow years on record and 1996 and 1999 were both high flow years. Both 1995 and 1998 were both average flow years. However, 1998 was one of the coolest summers on record. Thus, the water years used in the analysis result in a biased estimate, considering the probability that in the ten years of the opinion, low, medium and high flow years will be normally distributed. This bias is more pronounced for the fall chinook analysis which only includes 1995 – 1999 water years.

  In conducting alternative SIMPAS analyses, CRITFC employed a more representative technique, using a survival estimate for a low flow year, an average and high water year. To insure that all the data from 1994 –1999 was used in the analysis, each water year was placed in the appropriate category from low, medium, and high. Then an average survival for each water year category was calculated. This eliminated biasing the analysis by unequal weighting of water years.

- The estimates for pool survival are not adequate. CRITFC questions why the Biological Effects Team (BET), used a different technique than what was used by PATH in their analysis. PATH used the FLUSH model, which has a mechanistic methodology for fall chinook pool survivals and uses flow/travel time/survival relationships for the spring pool survival estimates. The advantage of this approach is that the reach-flow survival relationship has been validated in a life cycle analysis approach (see above comments under Flow, Survival and Productivity). Further, PATH identified in-river survival as a key uncertainty in their modeling process. Accordingly, the PATH team suggested that "well-planned" experiments needed to be developed to answer questions about passage model assumptions, for individual reaches. These experiments have not been developed nor have the questions been answered by SIMPAS. Rather, NMFS has enveloped SIMPAS in assumptions, replacing any lack of data with "professional judgment".

- Spill was evaluated for the years for which survival values were estimated (1994-1999). The actual levels of spill modeled for the draft opinion, and used as part of the validation for the no jeopardy assessment, may be based on levels of spill greater than what actually occur in the system under less than average, or near average flow years. The BiOp likely overestimates the benefits of spill based on the assumption that spill at each dam occurs up to the 120% gas waiver. In actuality, spill does not reach the 120% total dissolved gas level due to in river management being tied to the tailrace monitors and the 115% criterion. CRITFC staff attempted to estimate a better average for spill amount at the dams than the model in order to recalculate the base case survival estimates.

- The description of model calibration, using terms such as reasonable and similar, does not adequately describe either variability, the degree of uncertainty about the data generated by the model, or how well it fits the data used to calibrate it. Nowhere does NMFS show how the model was calibrated, or how well the data fit the calibration, nor was the model critiqued with independent peer review. Accordingly, it appears unwise to place any reliance on the model. How much weight would a reasonable person place upon an unknown structure or tool?

- Model assumptions are not tested. For example, survival estimates from Snake River are projected for the lower Columbia where data is not available. Thus, equal per mile survival is assumed for all segments of the river. No attempt is made to provide alternative analyses for other possible assumptions. For example, what if per dam survival is 10% higher or lower in the Lower Columbia? How would this affect the hydrosystem survival?

- All numbers in the model arel treated equally, whether those numbers are empirical (based on reach survival estimates), calculated (derived by partitioning a survival estimate into parts for each parameter identified - NMFS uses a survival estimate from the Lower Snake River to determine a per mile survival, then projects that to the lower river projects)) or based on professional judgment. These numbers are placed together into an equation, and the end number used to determine if a group of assumptions can be improved upon by comparison to another group of assumptions.

The danger of this approach is that it gives a false sense that the data are all of uniform value and are reliable. This illusion is carried through to the point of developing hydrosystem survival for Snake River and Mid-Columbia ESU's for chinook and steelhead. But these endpoint survival numbers are point estimates and have a range that depends upon the RPA measure chosen. No statistical analysis of variability is provided to give a sense of how precise or un-precise these estimates are.

Specific Comments Relating to parameters used in the model:

1. The Dalles powerhouse survival estimate. The model uses 90% for the current case and 92% for aggressive cases. Recent NMFS survival studies (Dawley 2000) indicated a survival estimate of 80% for spring and 82% for summer migrants, respectively. To insure that the results are conservative these values should be used in the modeling.

   If the current powerhouse survival is 80% to 82%, then the aggressive estimate also needs to reflect this lower number. The improvement for the aggressive analysis is based on improvements gained through the installation of Minimum Gap Runners (MGR's). However, improvements of the MGR's at Bonneville are uncertain. There was no statistically significant improvement, thus we question the 2% improvement that was assumed in the aggressive plan. Furthermore, no MGR installation is shown for the Dalles in the System Configuration Team's (SCT) Schedule, which currently extends into 2005. Thus the MGRs must begin to be installed after that time period. At most, one to two can be installed per year. Therefore, in five years at most only 10 would be installed at The Dalles, which would be less than half the powerhouse. So even if the MGR did show an improvement over current units (which is not the case given current studies), the full benefit would not be realized until after the period addressed by the opinion. This is not considered in modeling the aggressive case.

   Further, at The Dalles, SIMPAS estimates indicate that the greatest improvement in dam passage survival (for spring chinook) will occur over "existing conditions" where survival jumps from 90.8% to 97.8% under an aggressive mix alternative. This represents a 7% improvement in dam passage survival. In turn, NMFS translates this dam survival gain from (90.8*0.983) = 0.8925 under existing conditions to (0.973*0.983) = 0.956 under the aggressive mix alternative . This improvement is assumed by increasing spillway survival to 98% by reducing spill from 64% to 40% (based upon 1998-1999 survival studies see above comments on The Dalles Spill studies), and by increasing sluiceway survival from 94 to 96%. Sluiceway survival is assumed to be improved by repositioning the outfall. These assumptions, however, do not comport with all of the field study results. For example, research results from 2000 studies indicates that substantially more migrants are sent through the turbines with the reduction of spill from 64% to 40%. The 2000 studies also indicate that spillway survival is approximately 94%, while turbine survival is only 80%. Using this data in the model, dam survival is 0.929, and overall project survival is only 0.913. This example illustrates how NMFS optimistically uses questionable data, plugs it into the SIMPAS model, and extrapolates it in the CRI to show that performance standards can be met,

population growth rates can be met from meeting the performance standards and thus, the FCRPS can meet recovery levels under the RPA.

2. The raised spillway weirs (RSW) in the aggressive modeling case are assumed to have a spill efficiency ratio of roughly 3:1. This means that for each percent of flow spilled three percent of the juveniles are passed via the spill. No RSWs have been tested anywhere in the region so this assumed efficiency is complete speculation. NMFS had such speculations regarding the passage efficiency of the Lower Granite surface collector in the 1995-1998 FCRPS biological opinion, and NMFS delayed implementation of breaching based upon the hope that the technology would be successful. The structure, after an $80 million cost investment and five years of study, is being removed as a failed experiment. To be realistic, conservative and generous, an RSW passage efficiency estimate of 2:1 would be more appropriate. This is a 100% improvement over most spillways, which are considered to be a 1:1 spill ratio.

3. There is an assumed 10% improvement in pool survival under the aggressive modeling case. Again, CRITFC believes that, without drawdown and/or significant flow augmentation (not found in the draft opinion) that this is an unrealistic, speculative assumption. The improvement is generated from an assumed reduced delay in dam forebays and improved predation control measures. Reductions in delay are assumed to come from spill through the RSWs, which are speculated to move fish past the project quicker and with less turbulence, which in turn, makes them less vunerable to predation. This is based on the assumed benefits of an untested and uncertain passage technique. Further, in view of the millions of dollars already expended on the issue, CRITFC highly questions what additional measures can be accomplished to significantly reduce predation that have not already been implemented.

APPENDIX E
RISK ASSESSMENT FOR SPILL PROGRAM
DESCRIBED IN 2000 DRAFT BIOLOGICAL OPINION

TABLE OF CONTENTS

E.1 SUMMARY E-1

E.2 INTRODUCTION AND BACKGROUND E-1
E.2.1 1995 Spill and Risk Management Report E-2
E.2.2 NMFS 2000 Approach E-2

E.3 1995 TURBINE VERSUS SPILL MORTALITY RISK ASSESSMENT E-3
E.3.1 Juvenile Salmonid Assessment E-3
E.3.2 Adult Salmonid Assessment E-5

E.4 2000 TURBINE MORTALITY VERSUS SPILL MORTALITY ASSESSMENT E-7

E.5 SUMMARY OF BIOLOGICAL MONITORING SINCE 1995 . . . . . E-8
E.5.1 Results of Physical Monitoring Program, 1995 to 1999 . . . . . E-8
E.5.2 Results of Biological Monitoring Program, 1995 to 1999 . . . . . E-9
E.5.3 Adult Monitoring E-12
E.5.4 Resident Aquatic Species E-13

E.6 SUMMARY OF RESEARCH RESULTS E-15
E.6.1 Mortality E-15
E.6.2 Gas Bubble Trauma Signs E-15
E.6.3 Depth Compensation E-17

E.7 CONCLUSIONS E-18

E.8 REFERENCES E-20

TABLES

E-1 Criteria for ranking prevalence and severity of gas bubble trauma signs (NMFS 1997) E-10
E-2 Summary of severe GBT signs monitored at Lower Granite, Little Goose, Lower Monumental, Ice Harbor, McNary, John Day, and Bonneville dams E-11
E-3 Adult salmonid GBT recorded at FCRPS projects between 1996 and 1999 . . . . . E-14

FIGURES

E-1 Risk assessment model example E-6
E-2 Percent yearling chinook salmon examined for GBT from 1995 to 1999 that exhibited fin bubbles of rank 1 through 4 versus forebay TDG levels (average of 12 highest hours) measured the day the fish were examined (Rock Island Dam monitoring not included) E-12
E-3 Percent of steelhead examined for GBT from 1995 to 1999 that exhibited fin bubbles of rank 1 through 4 versus forebay TDG levels (average of 12 highest hours) measured the day the fish were examined (Rock Island Dam monitoring not included) E-13

E.1 SUMMARY

This paper addresses the 120% dissolved gas ceiling in light of the findings of the "Spill and 1995 Risk Management" report (1995 report) prepared by the region's fishery agencies and tribes (WDFW et al. 1995), the findings of research before and during implementation of the 1995 FCRPS Biological Opinion, and the results of the physical and biological monitoring program conducted from 1995 to the present. Two spill program scenarios are evaluated using the SIMPAS model, which compares the potential juvenile salmonid survival improvement due to increased spill against the risks of increasing total dissolved gas above the 110% water quality standard. The National Marine Fisheries Service (NMFS) concludes in this updated assessment that the risk associated with a managed spill program to the 120% total dissolved gas (TDG) level is warranted by the projected 4% to 6% increase in system survival of juvenile salmonids. Recent research and biological monitoring results support the findings of the 1995 report, which predicted that TDG in the 120%-to-125% range, coupled with vertical distribution fish passage information indicating that most fish migrate at depths providing some gas compensation, would not cause juvenile or adult salmon mortalities exceeding the expected benefits of spillway passage. NMFS finds little evidence that this expected survival improvement would be reduced by mortality related to gas bubble trauma (GBT). NMFS also concludes that physical and biological monitoring of GBT signs can continue to be used to indicate dissolved gas exposure in adult and juvenile salmon migrants.

E.2 INTRODUCTION AND BACKGROUND

Risk assessment is the comparison of alternative paths of action to determine the probability of an adverse outcome. The 1995 report was based on a risk model described by Rowe (1997). In that model, risk is characterized and managed by identifying the hazards and the degree of exposure to those associated with different paths of action. In the 1995 report, two paths of juvenile fish passage were compared: a) juvenile fish through turbines, where they are subjected to physical hazards, changes in pressure, etc., or, b) routing them over project spillways by increasing the volume of water spilled. The main hazard involved in the second alternative is the potential effect of dissolved gas supersaturation and the debilitating, and potentially lethal, GBT. The 1995 report found that, within limits, spill had merit compared with turbine passage. As a result of that report, NMFS recommended spill to achieve 80% fish passage efficiency (FPE) up to a gas level of 120% in the tailrace (and 115% in the forebay) at mainstem hydroprojects where juvenile salmon pass.

The region now has 5 years' experience in implementing the spill program recommended by the 1995 FCRPS Biological Opinion. Additional dissolved gas research has been conducted. Moreover, 5 years of physical and biological monitoring results are now available to characterize the results of the spill program adopted by NMFS in 1995. Finally, the NMFS SIMPAS model,

used to estimate the projected survival effects of management alternatives, was updated in 2000 with the most recent quantitative input to various fish passage functions. The model allows predicting the project and system survival effects for listed juvenile salmonids at different spill levels. Here, we investigate the risk to salmonids of TDG levels greater than the 110% water quality standard. The investigation does not assess risk to other aquatic species. For further information on that topic, see Schrank et al. (1996 and 1997); Ryan and Dawley (1998); and Ryan et al. (2000).

E.2.1 1995 Spill and Risk Management Report

In 1995, a group of the region's agencies and tribes developed the 1995 report, which evaluated the risks of alternate strategies for the passage of juvenile salmonids at hydroelectric projects in the Columbia River basin. The two main passage routes scrutinized were passage through turbines and voluntary spill at the FCRPS projects. The work was done jointly by technical staffs of the Columbia River Intertribal Fish Commission, the Idaho Department of Fish and Game, the Oregon Department of Fish and Wildlife, and the Washington Department of Fish and Wildlife. Also contributing to the report were the U.S. Fish and Wildlife Service, NMFS, and the Fish Passage Center.

Spill has long been known as a valid and relatively safe strategy for increasing passage efficiency and improving the survival of juvenile migrants. However, spill generates dissolved gas supersaturation, which represents a risk to fish if the gas level is too high. When the 1995 report was written, there had already been approximately 30 years of laboratory and field research on the subjects of spill, TDG production, the biological effects of dissolved gas supersaturation, and other hydroelectric project effects on juvenile and adult salmonid passage. The 1995 report reviewed the research on spill and its effect on dissolved gas generation and subsequent GBT and mortality in fish. Relative risks were then mathematically assessed on the basis of an analysis of quantitative information concerning direct fish mortality from both turbine and spill passage. The 1995 report concluded that, as long as spill-generated TDG levels did not exceed 120% to 125% supersaturation, the risk of passing juvenile salmonids through the spillways remained lower than the risk of passing juveniles through turbines. The 1995 assessment also indicated that the same level of TDG would not harm adult salmon.

E.2.2 NMFS 2000 Approach

The dissolved gas water quality standard was established in the 1970s by the U.S. Environmental Protection Agency (EPA). The standard is enforced by the water quality agencies in each state. The dissolved gas standard is limited to a dissolved gas supersaturation of 110%. It applies to all fish and aquatic life and incorporates a margin of safety. Since the implementation of the first biological opinion, the states recognized the value of spill to increasing the survival of

downstream migrants. They have, therefore, granted temporary waivers of the TDG standard to a level of 115% TDG in project forebays and 120% TDG in tailraces during the juvenile migration season. The pertinent question in this risk analysis concerns the increase in juvenile survival represented by the additional 5% to 10% of dissolved gas permitted by the states' temporary waiver limits.

NMFS employed the SIMPAS model to evaluate the potential increase in juvenile survival due to the difference in spill levels generating TDG of 110% or 120% supersaturation. The SIMPAS model includes all the current information on species-specific fish passage parameters: spill efficiency; fish guidance efficiency; spill/gas caps, turbine, spillway, sluiceway, and bypass survivals; and diel passage patterns.[1]

The increase in survival due to the added spill is compared with the risk potential due to the added 5% to 10% of TDG. The results of 5 years of monitoring TDG levels (during the 1995-to-1999 spill seasons) and the biological reactions in the juvenile migrant population detected by the monitoring program are reviewed. The results of research during the same period are also reviewed to validate the monitoring methods and to verify the assumptions of the SIMPAS modeling.

E.3 1995 TURBINE VERSUS SPILL MORTALITY RISK ASSESSMENT

E.3.1 Juvenile Salmonid Assessment

The hydroelectric projects on the Columbia and Snake rivers impede salmonid migrations (Raymond 1969, 1979). Passage of juveniles through turbines, bypass systems, and spill represents sources of injury and mortality (NMFS 2000a). For example, recent NMFS studies of turbine survival for yearling chinook in the Snake River produced estimates of 92.0% in 1993, 86.5% in 1994, and 92.7% in 1995 at Little Goose, Lower Monumental, and Lower Granite dams. Steelhead survival from turbine passage at Little Goose in 1997 was 93.4% (Muir et al., In review: No. Am. J. Fish. Mgt.).

The most benign method for improving passage is to pass fish over the project, through the spillway, and avoid the powerhouse altogether (NMFS 2000a; ISAB 1999). The range of spillway mortality for standard spillway structures is 0% to 2% (Whitney et al. 1997).

[1]For a more complete description of the SIMPAS model and a listing of its passage parameters, see Appendix D.

The 1995 report assessed the risks of turbine passage and spill as alternate routes of passage through FCRPS hydropower projects. Specifically, the 1995 assessment compared the anticipated mortalities from turbine passage with the mortalities that could occur as a result of elevated TDG due to spill and associated GBT effects. The assessment hypothesized that mortality due to controlled dissolved gas levels from the NMFS spill program would be less than mortality due to turbine passage.

The assessment methods required estimating turbine mortality under different river management (spill/no spill) schemes, and estimating mortality from TDG created by increased spill. Turbine mortality was then used as a benchmark for comparison with projected mortality from TDG under increased spill programs. At some level of TDG, juvenile mortality due to gas supersaturation will equal or exceed that due to turbine passage. Spill-generated TDG levels above that point will be increasingly detrimental to juvenile migrants.

Turbine mortality estimates were derived from 1992 smolt monitoring program data, which provided a measure of fish population size and timing. The numbers of fish passing through turbines were estimated by applying the fish guidance efficiencies identified in the Columbia Basin Fish and Wildlife Authority's Detailed Fishery Operating Plan to the population figures. The population numbers were also adjusted to reflect fish capture for the transportation program and for losses to the population from reservoir mortalities. Finally, the river project operations component of the assessment was chosen to represent three levels of spill:

1) Hydrosystem operated for power generation only (baseline, no spill)
2) Hydrosystem operated according to 1992 FCRPS Biological Opinion spill
3) Hydrosystem operated to 80% FPE (115% to 120% TDG spill caps)

Each operational scenario yielded an estimate of juvenile turbine mortality under the described conditions.

The estimates of mortality due to TDG were more difficult. In the mid-1990s, bioassays had determined lethal TDG levels primarily under shallow-water laboratory conditions, which are not representative of the conditions experienced by migrating juveniles. The Columbia River is sufficiently deep throughout the FCRPS that migrants could benefit from depth compensation for supersaturated conditions. In 1995, many fisheries scientists believed depth compensation was significant in determining fish responses to TDG.

Because of their depth limitations, the laboratory TDG bioassay data were not used in the 1995 assessment. Dissolved gas mortalities were estimated using the results of in situ field studies in which fish were exposed in live cages and held at specified depths. The exposures and amount of depth compensation experienced by the test fish were, therefore, more representative of the

condition experienced by migrants. Dissolved gas mortality functions were calculated from data for coho, chinook, and steelhead exposed at representative depths, to gas levels ranging from 110% to 140% and for periods from 3 to 92 days (Ebel 1969; Beiningen and Ebel 1969; Ebel 1971; Meekin and Turner 1974; Blahm et al. 1975, 1976; Dawley 1986; and Toner et al. 1995). The mortality function for dissolved gas, developed statistically, described the percent of fish mortality as a function of TDG. The analysis also considered exposure duration, species, and depth. The data were fitted to a logistical model.

The risk model used by the agencies and tribes in 1995 is demonstrated in Figure 1, which plots turbine mortality (y-axis) against percent dissolved gas (x-axis). The calculations of mortality, in numbers of juvenile fish, estimated the difference in project mortality between a no-spill (maximum turbine passage and mortality) and an 80% FPE scenario (minimum mortality due to maximized spill). The difference in mortality between the two extremes was termed a mortality "ceiling," and represents the expected benefit of 80% FPE spill up to the gas cap, excluding TDG-induced mortality. The expected benefit in terms of number of fish is shown as a horizontal line in Figure 1. The sigmoid line in the figure is an example of a mortality function curve, which represents the estimated loss of fish due to TDG. The point where the turbine mortality line and the gas mortality curve intersect is where the mortality due to dissolved gas from spill equals the mortality due to turbine passage. That is, additional spill and resulting gas would be predicted by the model to kill more fish than would turbine passage.

A shortcoming of the risk assessment model is determining how to incorporate exposure time in the mortality function. The 1995 report therefore assessed risk in two time frames, i.e., the model assumed that dissolved gas mortality was either instantaneous at the project, or occurred after an exposure period equal to the travel time from Ice Harbor Dam to Bonneville Dam. Even with such an oversimplification, the dissolved gas concentration at which no further benefit could be achieved by increasing spill exceeded the 120% tailrace gas cap set by the FCRPS 1995 Biological Opinion.

The 1995 report concluded that spill provided a safe route of project passage compared with turbines, up to the spill levels that would generate a downstream gas equivalent to 120% to 125% TDG in the tailraces.

E.3.2 Adult Salmonid Assessment

The 1995 report estimated potential adult mortality due to elevated TDG levels for chinook, sockeye, and steelhead. Using published laboratory and field mortality data for those species, the assessment focused on a TDG range of 115% to 130% and on actual river conditions and spill levels during the spring and summer. The analysts made two assumptions: 1) there would be no

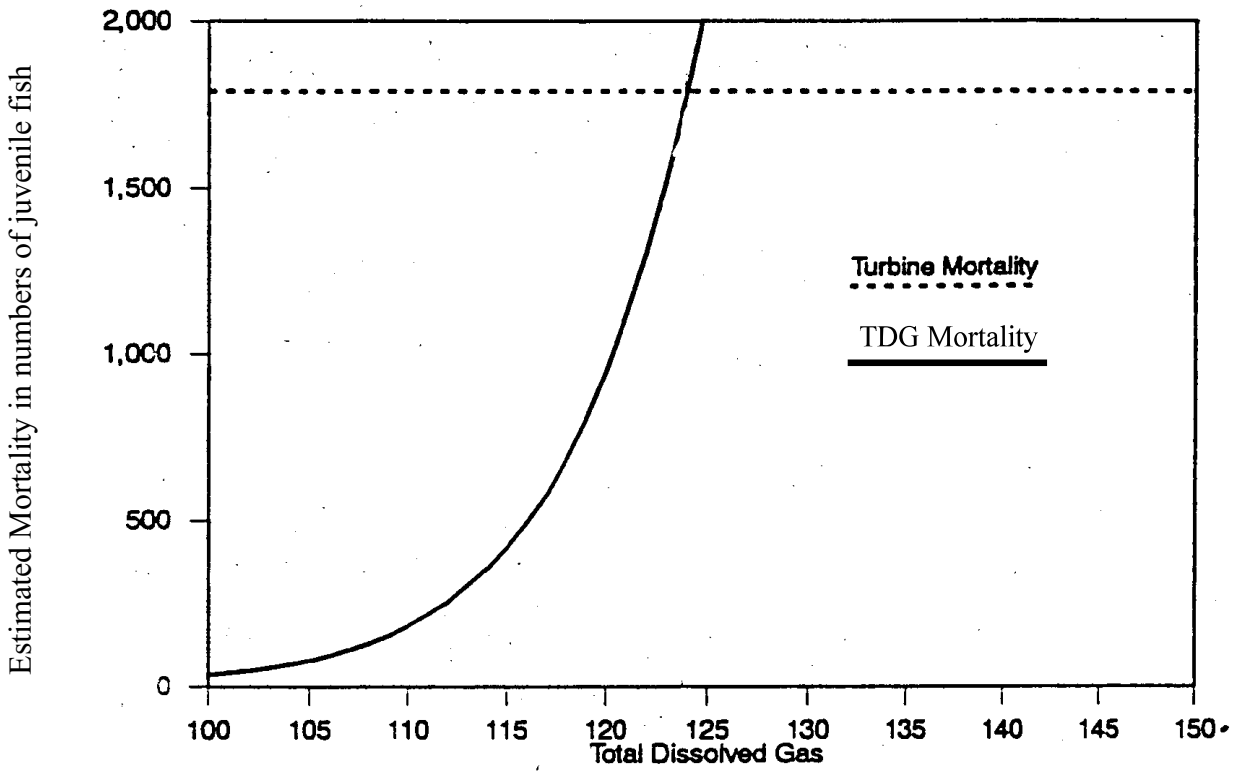


Figure E-1. Risk assessment model example.

dissolved gas-related mortality at gas levels less than 110%, and 2) only fish occupying water less than 3 meters deep would be vulnerable to GBT. The latter assumption factored in effects of depth compensation.

The model that was developed estimated the size of the population exposed, the exposure time, and the expected mortality for fish in three depth zones (0 to 1, 1 to 2, and 2 to 3 meters). Mortality was estimated by regression analysis for spring chinook, sockeye, and summer and winter steelhead.

The analysis projected no adult chinook, sockeye, or steelhead mortalities at 115% or 120% TDG, assuming depth compensation. Mortality for summer chinook and sockeye was predicted to increase between 125% and 130% TDG. The predicted mortality of steelhead at 125% and 130% was less than that of chinook and sockeye, because of the migration timing of the species.

Another step taken in this 1995 analysis considered the fate of the juveniles protected by an increased spill program, i.e., juveniles that were spilled and thus avoided turbine passage. The anticipated increase in numbers of juveniles was converted to an estimated survival-to-adult number. The adult equivalent estimate was also used to assess the impact of TDG on the adult population.

E.4 2000 TURBINE MORTALITY VERSUS SPILL MORTALITY ASSESSMENT

The 2000 FCRPS Biological Opinion analyzes the biological effects of many actions, strategies, and scenarios, separately or in concert. To assist in the biological analysis, a Biological Effects Team was formed. The team was one of five formed to assist in the Section 7 consultation process. It was agreed that the biological effects of juvenile salmonid passage measures, including spill, would be evaluated by the Biological Effects Team and NMFS using the SIMPAS model. The details of the biological effects analysis and the SIMPAS model are discussed in Appendix D.

The SIMPAS model is particularly appropriate for spill questions, because it accounts for successful passage through each route available to juvenile fish, including turbines, sluiceways, surface and conventional fish bypasses, and spillways. The model also accounts for juvenile fish transportation and reservoir passage. The model produces juvenile survival estimates at each project individually and systemwide. The model incorporates the latest qualitative and quantitative information on spill efficiency, fish guidance efficiency, turbine survival, bypass survival, spill/gas caps, spillway survival, sluiceway survival and diel passage patterns (NMFS 2000b,c,d,e).

The spill scenarios were analyzed for this assessment using the SIMPAS model. It was assumed that the 2000 FCRPS Biological Opinion reasonable and prudent alternative (RPA) spill program was fully implemented. The RPA condition was selected because the long-term TDG goal (i.e., over the next 10 years or so), as stated in Section 9.6.1.7.1 of the 2000 FCRPS Biological Opinion, is to reach the 110% standard in all critical habitat in the Columbia River and Snake River basins, including the mainstem. Achieving this goal in the long term still requires juvenile fish system survival levels to be consistent with the performance standards for the mainstem FCRPS hydropower projects (see Section 9.2.2.2.1 of the biological opinion).

The spill conditions in the SIMPAS model reflect current state water quality guidelines. TDG is 110% in Washington and Oregon. Each year since 1995, the states have temporarily waived the 110% limit and allowed spill to a gas level not to exceed 115% in project forebays or 120% in the tailrace. The modeled spill volumes are based on the current U.S. Army Corps of Engineers' estimates of spill expected to yield the above levels of TDG supersaturation. A 1995 water

condition was selected for the spill studies as an approximate average water condition.[2] The 1995 water year resulted in involuntary spill only at McNary Dam.

For the present assessment, SIMPAS survival modeling was conducted for juvenile spring chinook (yearling), juvenile fall chinook (subyearlings), and juvenile steelhead migrants under 110% TDG spill levels and under 115% or 120% TDG spill levels. Additional spill at the 115% or 120% TDG levels would yield an improvement of 5.7% in inriver survival for juvenile spring chinook yearlings. The increases in inriver system survival are estimated to be 4.9% for subyearling chinook and 3.9% for juvenile steelhead.

E.5 SUMMARY OF BIOLOGICAL MONITORING SINCE 1995

The 1995 FCRPS Biological Opinion called for physical and biological monitoring programs to accompany implementation of the spill programs. The purpose was to track and record spill, dissolved gas, and effects on aquatic biota. The physical monitoring program deployed about 40 dissolved-gas saturometers at various forebay and tailrace stations throughout the FCRPS. Some monitoring stations were also established and operated by the Mid-Columbia Public Utility Districts (PUDs).

The biological component of the monitoring program required collecting and examining juveniles and adult salmonids for GBT. Juveniles are collected as the fish pass through the juvenile collection/bypass facilities at Lower Granite, Little Goose, Lower Monumental, Rock Island (a Mid-Columbia PUD project), McNary, and Bonneville dams. The fish are inspected for fin, eye, and lateral line signs of GBT. Adults are examined at Bonneville and Lower Granite dams. Adults have also been examined at the Priest Rapids and Three Mile (Umatilla River) dams. All adults are examined for signs of GBT in the fins and eyes. Detailed results of the physical and biological monitoring programs are reviewed in annual reports to the Oregon Department of Environmental Quality (ODEQ) (NMFS 2000a).

E.5.1 Results of Physical Monitoring Program, 1995 to 1999

The physical monitoring program results from 1995 to 1999 should be differentiated into two conditions to clarify the potential impact of the NMFS spill program on salmonids. The two spill conditions are 1) a program managed or planned to keep spill levels within 115% or 120% TDG, and 2) involuntary, or forced, spill conditions. The first condition is controllable; spill for fish

[2]Specifically, the 1995 modified April-to-August runoff volume at Lower Granite Dam on the Snake River was 22.4 million acre-feet (maf), or 98% of average, while the April-to-August runoff volume for the Columbia River at The Dalles was 86.1 maf, or 94% of average.

can generally be managed within the state water quality limits in average to below-average runoff conditions. The second condition is uncontrollable because it results from average to above-average runoff that creates high river flows beyond the hydraulic capacity of the FCRPS powerhouses. The differences in the two spill conditions are reflected in the percent of days during the spring and summer migration periods when TDG exceeds 120% and 130% in the tailraces of lower Snake and Columbia River dams. For example, 1995 was the only year during the period with near-average runoff. The percent of days exceeding 120% TDG in 1995 was only about 8%, and for 130% TDG, only about 2%. The exceedances were due to short periods of involuntary spill, and to lack of gas-abatement structures at Ice Harbor and John Day dams. Thus, for most of the 1995 migration period, gas levels were managed to below 120% TDG.

That was not the case for the higher runoff years of 1996 through 1999. In most of those years, flows exceeded hydraulic capacity and caused involuntary spill for stretches of days. The highest runoff years were 1996 and 1997, which experienced 130% and 155% of average runoff in the Snake River and 122% and 121% of average runoff in the Columbia River, respectively. The 1997 April-to-August runoff volume at Lower Granite Dam on the Snake River, for example, was the third highest since 1928. During these two years, the percent of days exceeding 120% and 130% TDG was about 48% and 15% to 22%, respectively. Again, the exceedances were due largely to involuntary spill. In 1998 and 1999, runoff was 112% and 119% of average in the Snake River and 98% and 118% of average in the Columbia River, respectively. The percent of days during the migration period exceeding 120% TDG ranged between 16% and 18%, respectively, with only one day in 1998 exceeding 130% TDG. Most exceedances were due to involuntary spill.

The tailraces of John Day and Ice Harbor dams, however, regularly exceeded the state 120% waiver limit from 1995 to 1997. Ice Harbor tailwater exceeded 130% almost 44% of the migration period in 1996, and the John Day tailwater exceeded that level about 48% of the time in 1997. Those levels were due largely to the high runoff volumes and flows that frequently exceeded the hydraulic limits of the projects, but also to lack of gas-abatement structures. Installing gas-abatement structures at both Ice Harbor and John Day dams in 1998 and 1999 contributed to the observed reductions in the gas levels in the tailwaters of those projects. The number of days when TDG levels exceeded the waiver level was reduced on average by about 50 days in 1998 and about 10 days in 1999.

E.5.2 Results of Biological Monitoring Program, 1995 to 1999

The biological monitoring program has been implemented each spring and summer since 1995. The results from 1995 to 1999 are evaluated and presented in the NMFS annual reports to ODEQ (NMFS 1996, 1997, 1998, 1999, 2000a). On capture, juvenile fish are anesthetized and

examined for the presence and severity of GBT signs. The severity of the signs is ranked according to the criteria in Table E-1, with ranks 3 and 4 classified as severe.

Table E-1. Criteria for ranking prevalence and severity of gas bubble trauma signs (NMFS 1997).

Rank	Area Covered With Bubbles (%)
0	0
1	1 - 5
2	6 -25
3	26 - 50
4	> 50

GBT signs (bubbles and blisters in the fins, eyes, gills, lateral line, mouth, and skin) have been recognized since the late 1960s. However, no clear correlation has been made between the various signs and mortality. Although it is generally accepted that the proximate cause of death in fish is gill emboli (Maule et al. 1997), a nonlethal technique has never been developed to examine gill lamellae. Therefore, fin bubbles continue to be the sign conventionally used to monitor and rank for biological effects of TDG supersaturation.

An important application of the GBT ranking system is in managing the spill program. Early on, it was determined that action to reduce voluntary spill and TDG levels would be taken if more than 5% of the fish examined exhibited bubbles covering 25% or more (rank 3) of the surface of any unpaired fin, or if 15% of the fish showed any bubbles on unpaired fins. These are referred to as the spill program "action levels." The action levels incorporate a margin of safety and are based on uncertainties raised in earlier research by the U.S. Geological Survey, Biological Resources Division (Maule et al. 1997a, 1997b). Those studies found that significant mortality did not occur in the test fish until approximately 60% of the exposed population exhibited bubbles in the fins or 30% displayed bubbles covering 25% or more of any unpaired fin. The action levels were then reduced primarily because the research results indicated a substantial uncertainty between fin bubble percentage and the onset of mortality.

The data in Table E-2 were reported in the 2000 NMFS annual report to the ODEQ. Reported are the number and percent of juveniles with severe GBT signs (rank 3 or 4) observed in fish collected during the past 5 years. Table E-2 shows that severe signs were observed primarily in 1996 and 1997. The management strategy for the spill program is to reduce spill in response to severe signs. That has never happened during managed (or voluntary) spill conditions. For

example, in 1996 and 1997, when severe GBT signs were recorded, spill reduction was not an option because high runoff conditions exceeded the hydraulic capacity of FCRPS powerhouses. There were also six instances of severe or action-level signs in 1998. They occurred in the early part of the spill season, when flows were large and spill responsible for elevated TDG was due to involuntary conditions (Filardo, personal communication).

Table E-2. Summary of severe GBT signs monitored at Lower Granite, Little Goose, Lower Monumental, Ice Harbor, McNary, John Day, and Bonneville dams.

Year	Fish Examined	Severe GBT Signs	
		No.	%
1995	71,230	0	0.00
1996	38,925	47	0.12
1997	42,751	117	0.27
1998	46,498	6	0.01
1999	25,184	0	0.00

From 1995 to 1999, the smolt monitoring program collected and observed 192,832 juvenile salmonids for GBT signs in the mainstem Snake and lower Columbia rivers. A total of 3,033, or 1.6%, showed some signs of GBT in their paired fins. The yearly incidence of signs was related to TDG exposure. For 1996 and 1997, higher levels of TDG were associated with higher percentages of GBT signs in salmonids (3.2% to 3.3%). Whereas in 1995, 1998, and 1999, with lower levels of TDG, the percentage of fish showing signs ranged from only 0.04% to 0.7%.

Figures E-2 and E-3 display the percent of sampled yearling chinook and steelhead in the lower Snake and lower Columbia rivers with observed signs of GBT relative to the TDG levels and the ranked response. It is apparent that few fish exposed to TDG levels below 120% exhibited GBT signs. However, fish with signs of GBT that were exposed to gas levels above 120% showed both an increasing incidence and severity. The more severe signs of rank 3 follow a similar pattern but do not begin to appear until TDG exceeds 116% to120%. Rank 3 signs become more prevalent above 131% TDG. The more severe signs affect only about 0.5% of the fish collected throughout the 5 years of the monitoring program.

Over the same 5-year period, steelhead sampled in the smolt monitoring program that displayed signs of GBT showed exactly the same trends in incidence and severity as did chinook. Rank 3 signs became more prevalent above 131% TDG and only affected about 1% of the fish collected during the 5 years.

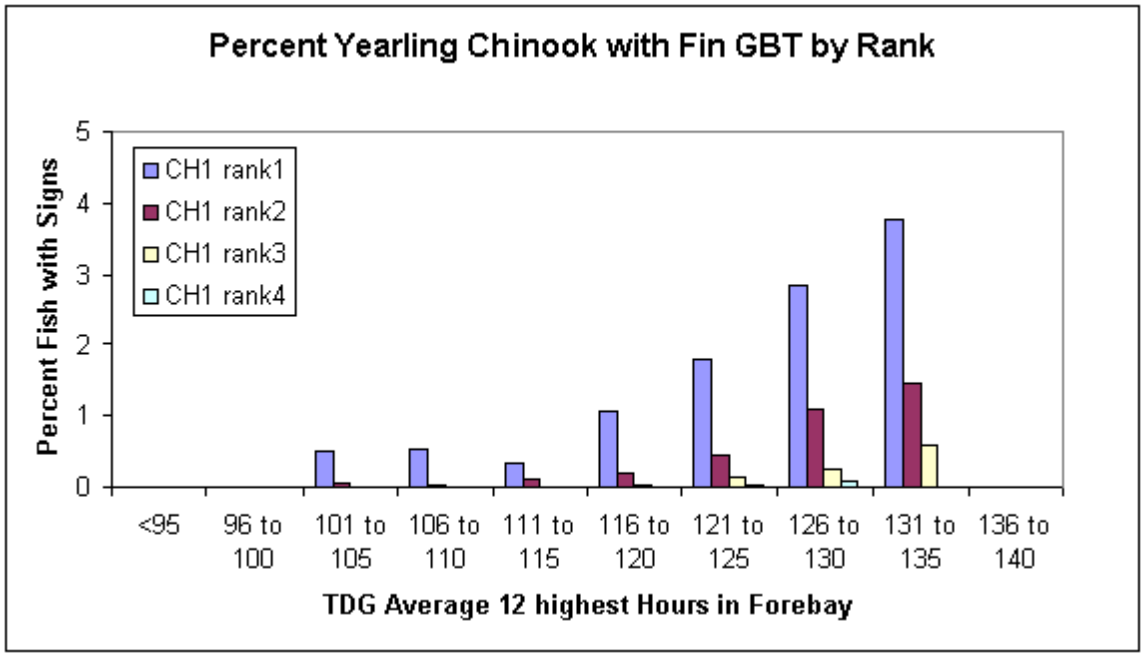


Figure E-2. Percent yearling chinook salmon examined for GBT from 1995 to 1999 that exhibited fin bubbles of rank 1 through 4 versus forebay TDG levels (average of 12 highest hours) measured the day the fish were examined (Rock Island Dam monitoring not included).

E.5.3 Adult Monitoring

Since 1996, adult fish have routinely been examined for the effects of TDG exposure during their upriver migration. The fish have been collected at Bonneville and Lower Granite dams, and less regularly at Ice Harbor, Priest Rapids, and Three Mile dams. Because of the high value of the adult fish and their potential for mortality due to handling, adult sampling for GBT is ancillary to other research on adult fish. The results of 4 years of adult fish monitoring are summarized in Table E-3.

As with juvenile monitoring, spring 1997 was the period of highest dissolved gas and the most significant degree of GBT in adult salmonids since the start of the spill program. In 1997, because of high runoff and forced spill conditions, TDG below Bonneville Dam was 135% or higher for 16 days, and above 130% for 24 days. During the spring and early summer, gas levels remained above 125% for an extended period in many sections of the river. Sockeye were most affected in 1997, with 15.6% of the fish collected at Bonneville Dam displaying signs of GBT. At Priest Rapids Dam, 4.2% of the collected sockeye were also affected. No sockeye were collected at Lower Granite Dam. During the same period, 0.5% of the chinook population was afflicted with GBT at Bonneville Dam, 0.1% at Lower Granite Dam, and 3.2% at Priest Rapids Dam. In the other years of monitoring (1996, 1998, and 1999), only a small number of fish collected at the sampling sites displayed signs of GBT. At Bonneville Dam, for example, none of the caught fish showed GBT signs.

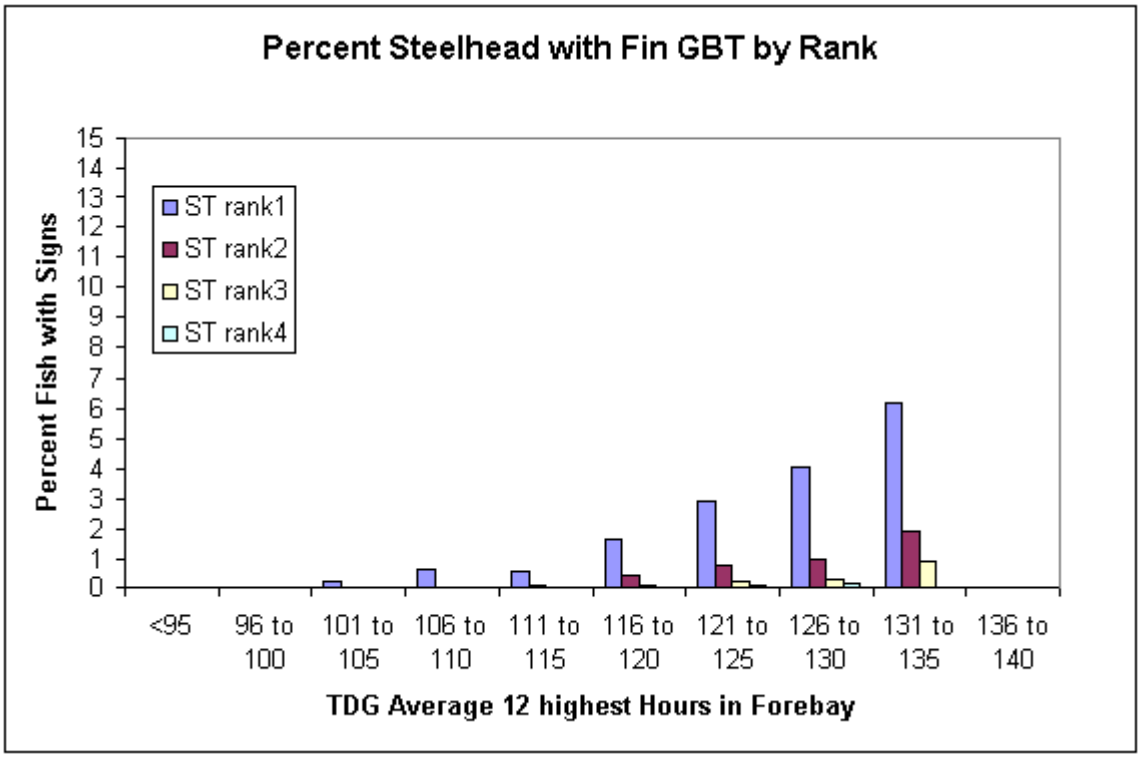


Figure E-3. Percent of steelhead examined for GBT from 1995 to 1999 that exhibited fin bubbles of rank 1 through 4 versus forebay TDG levels (average of 12 highest hours) measured the day the fish were examined (Rock Island Dam monitoring not included).

The action levels established by NMFS for adults are more stringent than those for juveniles. The adult levels stipulate reduction of spill if two or more fish are observed to have external signs of GBT in a single day at a sampling site. Action is also prompted if signs are found on one fish in two or more sampling periods at the same project. The results of the monitoring program show that the action levels were surpassed only in the high spill years of 1996 and 1997. However, the substantial involuntary spill in those years eliminated the ability of river managers to respond to the action levels by reducing spill and the associated TDG levels.

E.5.4 Resident Aquatic Species

The sensitivity of resident fishes and invertebrates to TDG supersaturation was investigated in the early 1990s. Species observed for GBT signs included suckers, sculpins, sticklebacks, and several minnows as well as crayfish, clams, and insect larvae. Gas exposure levels ranged from 117% to 130%. Only rarely were GBT signs observed (Toner 1993). It was concluded that resident fishes and invertebrates are relatively tolerant of elevated TDG.

Table E-3. Adult salmonid GBT recorded at FCRPS projects between 1996 and 1999.

Site	Species	Fish Examined	Fish With GBT Signs	
			No.	%
1996				
Bonneville	Chinook	*	4	0.2
	Steelhead	*	3	0.1
	Sockeye	*	1	0.05
Lower Granite	Chinook	2652	4	0.1
1997				
Bonneville	Chinook	1042	5	0.5
	Steelhead	336	24	7.1
	Sockeye	648	101	15.6
Lower Granite	Chinook	6312	5	0.1
Priest Rapids	Chinook	280	9	3.2
	Steelhead	95	2	2.1
	Sockeye	852	36	4.2
1998				
Bonneville	Chinook	729	0	0.0
	Steelhead	260	0	0.0
	Sockeye	184	0	0.0
Lower Granite	Chinook	3755	4	0.1
1999				
Bonneville	Chinook	745	0	0.0
	Steelhead	273	0	0.0
	Sockeye	184	0	0.0
Lower Granite	Chinook	3755	4	0.1

*Total number of fish examined = 2026.

More recent studies have concluded that the current knowledge about TDG effects on resident fish allows reliance on a model to predict signs in resident species on the basis of physical measurements of TDG. Ryan and Dawley (1998) investigated the responses of resident fish held in net pens. They observed that a relationship could be developed to predict signs at various TDG levels for resident species. Shrank et al. (1998) developed an algorithm model that predicts GBT signs in resident fishes where continuous TDG monitoring is available. They concluded that extensive biological monitoring of resident species is unnecessary.

E.6 SUMMARY OF RESEARCH RESULTS

E.6.1 Mortality

Seasonal periods of high spill and gas supersaturation in the Columbia River basin system have been a problem for decades. 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).

Ebel et al. (1975) reviewed the findings of several bioassay studies and reported substantial fish mortality at 115% TDG after 25 days of exposure in shallow water. Blahm et al. (1973) recorded 98% (chinook) and 80% (coho) mortality at greater than or equal to120% TDG at a depth of 1 meter. However, in 2.5 meters at the same TDG level, mortalities were reduced to 8.7% and 4.2%, respectively. If fish are allowed access to deeper water during the tests, mortality will be observed at TDG levels greater than 120% after more than 20 days. Dawley et al. (1975) found that all species tested in deep-water tanks reached 50% mortality in 24 hours at 130% TDG, but had no recorded deaths at 110% TDG in 24 hours.

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 free-flowing river environment could be set as high as 120% TDG (Weitkamp and Katz 1980).

E.6.2 Gas Bubble Trauma Signs

Columbia River fish managers realized early that the effects of TDG on fish populations could not be assessed merely on the physical measurements of dissolved gas. Knowledge of the incidence, severity, and progression of GBT signs was essential.

An important finding in early research was that death from TDG exposure can occur in the absence of any external signs (Meekin and Turner 1974, Weitkamp 1975, and Bouck et al. 1976). Signs of GBT were found to be most severe in lower, marginally lethal gas supersaturation exposures (Bouck et al. 1976). Several researchers observed that fish that do not die from GBT may undergo a reduction in prevalence and severity of signs on return to air-equilibrated water (Meekin and Turner 1974, Blahm et al. 1973, Weitkamp 1974, Knittel et al. 1980, Dawley and Ebel 1975). Ebel et al. (1975) also noted that the signs of GBT disappear after death. The results

from these early studies indicate that it is necessary to monitor migrants for signs of GBT as the biological threshold indicator of TDG supersaturation stress. However, there is no clear set of signs, or a clear time correlation between TDG level and exposure duration, that allows impending fatality to be predicted.

The signs of GBT in adults are like those observed in juveniles. They include emphysema, circulatory emboli, tissue necrosis, and hemorrhages in brain, muscle, gonads, and eyes (Weitkamp and Katz 1980). Nebeker et al. (1976) found that death in adults was due to massive blockages of blood flow from gas emboli in the heart, gills, and other capillary beds. Investigators in the 1970s reported many and varied lesions in fish exposed in the 115%-to-120% TDG range in shallow water. At higher gas exposures, e.g.,120% to 130% TDG, death frequently ensued before GBT signs appeared (Bouck et al. 1976). External signs of GBT, e.g., blisters forming in the mouth and fins of fish exposed to chronic high gas, often disappeared rapidly after death. The signs were largely gone within 24 hours (Countant and Genoway 1968).

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 monitoring program. Maule et al. (1997) found that no single GBT sign can be relied on as the sole precursor of lethal conditions in the field. However, GBT signs did worsen with longer exposure to the conditions. However, it is necessary to better understand the severity and prevalence of signs in several tissues and relate them to exposure time and adverse reactions. The conventional signs used in GBT studies and monitoring are the lateral line, fins, and gill filaments.

According to Maule et al. (1997a), Elston et al. (1997), Hans et al. (1999), and Mesa et al. (1999), each of the following tissues manifests unique tissue bubble characteristics:

Lateral line	Earliest tissue to display signs Signs may disappear quickly Progressive worsening with time Low degree of individual specimen variation Progressiveness of sign is indicator of exposure severity May not be relevant in chronic exposure to low TDG
Fins	Bubbles may not develop in acute exposure High prevalence in most exposures Progressive worsening with time Bubbles are persistent Quantitative ranking of severity difficult
Gills	Bubbles proximate cause of mortality Little progression with time High degree of variation Poor predictors of severity Difficult to observe and quantify Bubbles may collapse easily on recompression

Maule et al. (1997) reviewed the implications of their findings with lateral line, gill, and fin signs as they might relate to monitoring programs. Lateral line bubbles were often the first observed. They showed progression with exposure and displayed little variation between specimens, but developed slowly under chronic, low gas treatments. Gill bubbles were usually the likely cause of death but did not progressively worsen. Individual variations were high in gill bubbles.

Although fin bubbles are prevalent and worsen with time, the practical use of fin bubbles as an indicator is hindered by lack of a rigorous quantitative method for evaluating severity. Mesa et al. (1999) summarized the findings of studies of GBT signs. Mesa pointed out the usefulness of the progressive nature of signs to monitoring programs, but also highlighted the following impediments:

1. Variability in persistence of GBT signs
2. Inconsistent relation of GBT signs to mortality
3. Insufficient knowledge of relation between exposure history and development of GBT signs
4. Extreme amount of variability of GBT signs

In spite of this, Maule et al. (1997) observed that GBT is most often progressive, and that 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. If TDG is low and passage time exceeds the threshold time for development of signs, the juveniles will have moved beyond dissolved gas effects of the river.

E.6.3 Depth Compensation

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. Weitkamp (1976) observed that juvenile salmonids held in live cages up to 4 meters deep in the Columbia River suffered no mortality in test ranges from 119% to 128% TDG. Dawley et al. (1975) conducted tests in a 10-meter-deep tank and found no steelhead mortality at 130% TDG and no spring chinook mortality at 133 % TDG. GBT signs were noted in both species, however.

Technological advances provide ways of studying depth compensation more closely. Using a pressure-sensitive radio frequency tag accurate to 0.3 meters of the true depth, Maule et al. (1997) 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%.

In subsequent years, Beeman et al. (1998, 1999) employed depth-sensitive radio tags to determine the depths of juveniles from Ice Harbor to McNary Dam. The 1997 studies indicate that fish were tracked at depths between 1.8 and 2.5 meters in water with a surface TDG level of 120%. The recorded depths would have provided protection and reduced the risk of GBT. The next year, the median depth of juveniles in McNary pool was sufficient to protect fish from TDG levels of between 117% and 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 authors concluded that a voluntary spill program with gas caps of 115% in forebays and 120% in tailraces can be expected to prevent gas bubble trauma in juvenile chinook and pose little threat to the more sensitive steelhead.

Gray and Haynes (1977) reported that spring and fall chinook adults implanted with pressure-sensitive radio transmitters swam deeper in gas supersaturated water than in air-equilibrated conditions. They concluded that 89% of the test fish migrated at a depth providing compensation for gas levels that would normally prove lethal.

More recent studies have employed a data storage radio tag to record both the depth and temperature history of migrating adults. Preliminary analysis of results indicate that tagged fish migrate in the depth range of 1.5 to 4 meters, some deeper than 4 meters. Thus, it appears that most of the chinook or steelhead adults may be negotiating the lower Snake River at compensatory depths for gas levels to at least 130% (Bjornn, personal communication, 2000).

E.7 CONCLUSIONS

A risk assessment was described earlier as a comparison of alternative paths to consider the probability of adverse action. Using the SIMPAS model, it was determined that an increase of 4% to 6% in system survival of juveniles would result from spill up to the biological opinion gas cap, i.e., 120% TDG, as compared to spilling to the 110% water quality standard. The question is whether there is any adverse effect resulting from the 10% increase in TDG. The potential adverse effects of this TDG increase can be judged by reviewing the findings of the 1995 report, the information gained in the last 5 years of monitoring, and relevant research.

The 1995 risk assessment estimated turbine mortality and compared it with a TDG mortality curve. The report concluded that, at the point where projected dissolved gas mortality equaled the lethality of turbine passage, higher TDG levels due to additional spill beyond a certain point would be counter-productive. That point ranged between 120% and 125% TDG. The assessment was conducted for spring, summer, and fall chinook, sockeye, and steelhead—the salmonid species of concern. The 1995 report concluded that a spill level of 120% to 125% TDG represented a conservative, controllable, and reasonable risk compared with turbine passage. Since a managed biological opinion spill program will result in gas up to 120% TDG, spill to this gas level is expected to provide a safer route of project passage than turbine passage.

The 1995 report also strongly urged establishing monitoring programs to track dissolved gas and monitor for signs of GBT. The results of 5 years of physical monitoring show that TDG generated as a result of implementing the spill program is adequately detected and recorded. When water conditions allow voluntary spill to increase FPE, the spill and resulting dissolved gas can be managed to comply with the temporary state waivers. In periods of involuntary spill, the sensitivity of the monitoring system records the frequency, intensity, and duration of high levels of gas supersaturation, as in 1996 and 1997. The physical monitoring system also demonstrates the beneficial effects of the construction and operation of gas-abatement structures. For example, after spillway deflectors were built at Ice Harbor and John Day dams, their gas-abating effects were reflected in the physical monitoring data.

The biological component of the 5-year monitoring program is consistent with TDG records. When the TDG exceeds the waiver limits, a biological effect is recorded in both the smolt and adult monitoring program (Tables E-2 and E-3). For example, severe signs (rank 3) of GBT were restricted to the years 1996 and 1997 during the periods of highest involuntary spill, which resulted in TDG levels of 130% or more on many days. Although severe signs have been noted in the monitoring program, such instances have been rare and confined to periods of involuntary spill when gas levels are greater than 120% TDG.

GBT in juvenile salmonids is observed at all gas levels. Even at a relatively low gas supersaturation level of 110%, signs can develop if the exposure is long and the water is shallow. However, based on 5 years of data from the biological monitoring program, the average incidence of GBT signs has been low. The accumulated data on GBT in chinook and steelhead show few GBT signs below 120% TDG. When fish with signs are exposed to gas levels above120%, the incidence and severity of GBT signs increase. A similar pattern is observed in fish with the more severe ranks 3 and 4 signs. Only few fish with severe GBT signs are detected until TDG approaches 130%, and the prevalence of signs does not begin to increase until TDG is between 121% and 125%. The overall number of fish affected with GBT signs proved to be less than originally assumed in the 1995 report.

The monitoring program for adult salmonids shows a similar relationship between gas bubble signs and TDG. For example, when the inriver TDG level is below 120%, few adult fish—in some cases none—display signs of GBT. Oregon and Washington used that information, coupled with the extreme importance of adult migrants to salmon recovery efforts, to dispense with continued adult monitoring (and associated handling) requirements in their 1999 water quality waiver stipulations. Investigators observe adult tolerance to TDG and hypothesize that it is attributable to the migration depth of adult salmonids. The depth-sensitive radio tags being used in adult migration studies now corroborate that adults migrate at depths up to 4 meters and find depth compensation protection from GBT. Thus, NMFS believes that the 120% tailrace gas cap recommended by the 1995 FCRPS Biological Opinion places no special TDG burden on adult migrants.

The results of the 1995-to-1999 monitoring program are consistent with reports in the literature on dissolved gas and gas bubble disease research. In the late 1960s and in the 1970s, studies

used dissolved gas exposures in the 110%-to-140% TDG range. In deep-tank or field studies, few effects were noted below 120% TDG, unless the exposure periods were very long (weeks).

From analysis of the biological monitoring program, NMFS concludes that biological monitoring of GBT signs can continue to be used to indicate dissolved gas exposure in adult and juvenile salmon migrants. The monitoring program indicates that the prevalence of GBT signs in the adult and juvenile salmonid migrant populations is well below the action levels supported by GBT mortality research, as long as TDG levels are kept below the levels recommended in the 2000 FCRPS Biological Opinion.

NMFS also concludes that the apparent contradiction between the current 110% TDG water quality standard limit and the biological opinion TDG limits is explained as an effect of depth compensation in migrating adult and juvenile salmonids. Finally, NMFS concludes that the risk associated with a 10% exceedance of the 110% TDG standard is more than compensated for by the improvement of an estimated 4% to 6% in FCRPS passage survival for juvenile salmon. NMFS finds little evidence that this survival improvement would be reduced by GBT-related mortality.

It should be kept in mind that the present assessment narrowly focused on salmonid migrants in the relatively deep mainstem reaches of the Columbia and Snake rivers, and was set against the mitigating factor of improved system passage survival. Applying the conclusions toward a change in national or state water quality standards would be inappropriate without additional research and monitoring data on other aquatic species and habitats.

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State, Federal, and Tribal Anadromous Fish Managers Comments on the Northwest Power Planning Council Draft Mainstem Amendments as they Relate to Flow/Survival Relationships for Salmon and Steelhead

FINAL DOCUMENT

January 2003

Executive Summary

of the State, Federal, and Tribal Anadromous Fish Managers Comments on the Northwest Power Planning Council Draft Mainstem Amendments as they Relate to Flow/Survival Relationships for Salmon and Steelhead

1. The state, federal, and tribal anadromous fish managers reviewed the NPPC's draft Mainstem Amendments to the Columbia River Basin Fish and Wildlife Program, which are contained in Council Document 2002-16. This review focused on the scientific information, as anticipated in section 839(h)(B) of the Northwest Power Act, regarding the effect of flow on salmon and steelhead survival.

2. The Council draft mainstem amendment document relies heavily on a conclusion from Giorgi et al. (2002) questioning the scientific basis of a flow survival relationship. There was little reliance by the Council on recommendations or comments of the fish and wildlife management agencies, scientific support for flow-survival relationships previously summarized in NMFS (2000) white papers, or recently peer-reviewed articles on chinook summer migrants.

3. The Council did not seem to heed the caution from the ISRP review that the Giorgi et al. (2002) report concerning a flow survival relationship was "…very conservative in drawing statistical conclusions. From a purely statistical standpoint, tests that fail to show statistical significance in data can be definitive in stating *no effect was found*, yet these tests do not definitively prove the absence of an effect."

4. The assessment and conclusions of the state, tribal and federal anadromous fish managers regarding the mechanisms by which flow and water velocity may affect juvenile survival in freshwater and from migrating smolt to adult return have been summarized in this paper. This includes a summary on juvenile migratory characteristics related to flow and spill that also provide evidence of flow-survival relationships, and the supporting empirical evidence from patterns of smolt-to-adult return rates (SARs) and life cycle survival analyses (ratio of recruits to the spawning grounds vs. spawners the previous generation; S/S).

5. The conclusion of the state, tribal and federal salmon managers, based on review of the scientific information regarding the effect of flow on salmon and steelhead are:
    a. **Juvenile steelhead and chinook spring migrants**
        i. A water travel time/ survival relationship exists for spring migrating chinook and steelhead of Snake River and Mid-Columbia River origin.
        ii. A water travel time and fish travel time relationship exists for spring migrating chinook and steelhead.
        iii. Within the management range of the Biological Opinion and the flow spill risk analysis dissolved gas levels of 125% there is minimal risk of reducing survival by increasing spill.
        iv. It is difficult to define a flow survival relationship because survival is the combined result of many interacting variables and the methodology for

estimating survival does not lend itself to identifying each individual environmental or biotic variable individually.

b. **Juvenile fall chinook migrants**
   i. Wild subyearling fall chinook salmon spend from 20 to 42 days in Lower Granite Reservoir primarily during the months of July and August.
   ii. Meeting summer flow targets decreases the time young fall chinook salmon spend in Lower Granite Reservoir by 1 to 5 days.
   iii. Survival of wild subyearling Snake River fall chinook is influenced simultaneously by flow and temperature.
   iv. Meeting summer flow targets increases flow and decreases temperature
   v. Meeting summer flow targets in July and August increases survival of wild subyearling fall chinook migrants.
   vi. Shifting flow augmentation from July and early August to later times in the year would decrease survival of the largest portion of the wild subyearling fall chinook salmon run.

c. Adult return analysis
   i. Numerous mechanisms exist by which flow and water velocity may affect survival from migrating smolt to adult return.
   ii. Juvenile migration conditions and ocean climate conditions were both influential in explaining patterns of adult recruitment of Snake River spring and summer chinook (spawner to spawner ratio).
   iii. The BIOP flow targets appear to represent a minimum needed to maintain the Snake River spring summer chinook populations for average to good ocean conditions and provide inadequate protection for poor ocean conditions.
   iv. The Councils proposed relaxation of spring flow targets would increase water travel time and reduce protection against population declines and the likelihood of rebuilding spring and summer chinook stocks.
   v. Juvenile migration conditions and ocean climate conditions were both influential in explaining patterns of SARs in Snake River spring and summer chinook and steelhead.
   vi. Relaxation of Spring flow objectives would likely decrease the SARs of wild Snake River spring and summer chinook and steelhead.

State, Federal, and Tribal Anadromous Fish Managers Comments on the Northwest Power Planning Council Draft Mainstem Amendments as they Relate to Flow/Survival Relationships for Salmon and Steelhead.

Introduction

The initial recommendations for the Northwest Power Planning Council Fish and Wildlife Program were submitted to the Northwest Power Planning Council under the auspices of Section 4(h) of the Northwest Power Act by the state, federal and tribal salmon managers in November of 1981. Flow and spill for the juvenile out migration of salmon and steelhead were critical facets of those recommendations. The joint recommendations of the salmon management entities were based upon passage and migration data and analysis collected to the date of the initial Fish and Wildlife Program. Over the past decades significant additional study and analysis has taken place.

The Council draft mainstem amendment document relies heavily on a conclusion from Giorgi et al. (2002) questioning the scientific basis of a flow survival relationship. There was little reliance by the Council on recommendations or comments of the fish and wildlife management agencies, scientific support for flow-survival relationships previously summarized in NMFS (2000) white papers, or recently peer-reviewed articles on chinook summer migrants. The Council did not seem to heed the caution from the ISRP review that the Giorgi et al. (2002) report was "…very conservative in drawing statistical conclusions. This fact needs to be understood for proper interpretation of the report. From a purely statistical standpoint, tests that fail to show statistical significance in data can be definitive in stating *no effect was found*, yet these tests do not definitively prove the absence of an effect." See Peterman (1990) for a review of this problem in fisheries research and management.

This paper briefly summarizes the assessment and conclusions of the state, tribal and federal anadromous fish managers regarding the mechanisms by which flow and water velocity may affect juvenile survival in freshwater and from migrating smolt to adult return. This includes a summary on juvenile migratory characteristics related to flow and spill that also provide evidence of flow-survival relationships, and the supporting empirical evidence from patterns of smolt-to-adult return rates (SARs) and life cycle survival analyses (ratio of recruits to the spawning grounds vs. spawners the previous generation; S/S). The document is organized in terms of juvenile migration characteristics and adult analysis. The conclusion of the state, tribal and federal salmon managers, based on review of the scientific information as anticipated in section 839(h)(B) of the Northwest Power Act, regarding the affect of flow on salmon and steelhead are:

Juvenile steelhead and chinook spring migrants

- A water travel time/ survival relationship exists for spring migrating chinook and steelhead of Snake River and Mid-Columbia River origin.
- A water travel time and fish travel time relationship exists for spring migrating chinook and steelhead.

- Within the management range of the Biological Opinion and the flow spill risk analysis, there is minimal risk of reducing survival by increasing spill up to dissolved gas levels of 125%.
- It is difficult to define a flow survival relationship because survival is the combined result of many interacting variables and the methodology for estimating survival does not lend itself to identifying each individual environmental or biotic variable individually.

Juvenile fall chinook migrants

- Wild subyearling fall chinook salmon spend from 20 to 42 days in Lower Granite Reservoir primarily during the months of July and August
- Summer flow augmentation decreases the time young fall chinook salmon spend in Lower Granite Reservoir by 1 to 5 days
- Survival of wild subyearling Snake River fall chinook is influenced simultaneously by flow and temperature
- Summer flow augmentation increases flow and decreases temperature
- Summer flow augmentation in July and August increases survival of wild subyearling fall chinook migrants
- Shifting flow augmentation from July and early August to later times in the year would decrease survival of the largest portion of the wild subyearling fall chinook salmon run

Adult return analysis

- Numerous mechanisms exist by which flow and water velocity may affect survival from migrating smolt to adult return.
- Juvenile migration conditions and ocean climate conditions were both influential in explaining patterns of adult recruitment of Snake River spring and summer chinook (spawner to spawner ratio)
- The BIOP flow targets appear to represent a minimum needed to maintain the Snake River spring summer chinook populations for average to good ocean conditions and provide inadequate protection for poor ocean conditions
- The Councils proposed relaxation of spring flow targets would increase water travel time and reduce protection against population declines and the likelihood of rebuilding spring and summer chinook stocks.
- Juvenile migration conditions and ocean climate conditions were both influential in explaining patterns of SARs in Snake River spring and summer chinook and steelhead.
- Relaxation of Spring flow objectives would likely decrease the SARs of wild Snake River spring and summer chinook and steelhead

Background of Flow Related Effects on Salmonid Smolt Travel Time, Rate of Seaward Movement, and Survival and Adult Returns

The analyses are approached in three components, the Snake River from Lower Granite to McNary Dam, Mid-Columbia from Rock Island to McNary and Lower Columbia River reaches from McNary to Bonneville tailrace. The following assessment focuses on the migration characteristics of juvenile salmonids including; travel time (migration speed), rate of seaward

movement, survival and migration timing, addressing these migration characteristics and the suite of biotic and abiotic factors that affect them.

Increases in flow in the hydrosystem are thought to be beneficial to migrating young salmonids for several reasons. These species evolved in systems without dams and were dependent on the river current to aid in their migration to the ocean. The migration of spring/summer and fall chinook and steelhead was timed with periods of high spring runoff. During a free-flowing condition Snake River yearling chinook and steelhead migrated to the ocean in about $^{1}/_{3}$ to ½ the time that is now observed with the dams in place. Dam construction changed juvenile fall chinook salmon life history in the Snake River basin by shifting production to areas with relatively cool water temperatures and comparatively lower growth opportunity. Consequently, young fall chinook salmon do not attain migratory status until late spring and the majority of the wild fish are present in lower Snake and Columbia River reservoirs in July and August after spring runoff is complete (Connor et al. 2002). Increases in the time spent in the reservoirs increases the exposure time to higher temperature and predators, now more abundant in the reservoir system than in pre-dam riverine conditions. (Poe et al 1991, Poe et al 1994) In addition to the direct effects of increases in flow on downstream passage of smolts, there are several other flow related mechanisms that manifest in life history constraints hence smolt survival. Increases in flow are associated with decreases in temperature and increases in turbidity. When flow falls to low levels, the accompanying increases in temperature increase the energetic demands for migrating smolts, increase their susceptibility to disease, disrupt smoltification, and increase the energy demands of predators hence predation on smolts. Low turbidity increase the susceptibility of smolts to visual predators such as fish and birds. Studies also suggest that the extended time smolts spend in freshwater affect marine survival by depleting energy reserves before the smolts arrive at the ocean. This phenomenon is especially prevalent under low flow conditions (Congelton, ACOE Delayed Mortality Workshop). A delay in seawater entry might also disrupt physiological changes necessary for adapting to saltwater. Decreased flows may also form greater physical barriers with the freshwater/saltwater interface (Schreck and Stahl 1998).

Travel time is one of the key migrational characteristics reflecting the dynamics of the migration of juvenile salmonids. The physiological condition of smolts changes over time and arrival at the estuary during the “biological window” determines the success of the smolts transition to seawater. Studies conducted since 1998 (Congleton et al., 2000, 2001 and 2002) have observed the rate of energy use and the blood chemistry changes that occur in fish as they migrate from hatcheries above Lower Granite Dam to Bonneville Dam In general, the juvenile chinook salmon studied were in negative energy balance throughout the downstream migration. The low flows in 2001 caused fish to undergo a migration that was significantly longer and the low flows and extended travel times resulted in the exhaustion of lipid reserves at points further upstream and greater use of protein reserves than in earlier years. The use of protein reserves means that muscle mass is metabolized and the activities of critical rate-limiting enzymes involved in metabolism, saltwater adaptation, and other vital functions may be reduced (Congleton, 2002).

Giorgi et al. (2002) points to these life-history constraints as rationale for flow augmentation. They provided information supporting increased migration rates with increases in flow for yearling chinook and steelhead (Sims and Ossiander 1981, Berggren and Filardo 1993). Most of

these analyses demonstrate increasing migration speeds by increasing flows provides the greatest benefits at lower flows. Regardless of flow level, several studies have produced equivocal results with respect to the relation between flow and seaward movement of summer migrating subyearling chinook salmon. Berggren and Filardo (1993), Giorgi et al. (1997), and Tiffan et al. (2000) studied ocean-type chinook salmon passing downstream in Columbia River reservoirs. Berggren and Filardo (1993) concluded that seaward movement of summer migrants increased as flow increased, thus flow augmentation helps to mitigate dam-caused passage delays. Tiffan et al. (2000) concluded that flow was weakly related to seaward movement. Giorgi et al. (1997) concluded that there is no evidence for a relation between downstream migration rate and flow. A recent study, however, showed that wild subyearling fall chinook salmon progress through a series of complicated migrational behaviors during which their response to changes in flow varies (Connor et al. In press a). Subyearling fall chinook salmon respond to increases in flow as they pass downstream from the free-flowing Snake River to Lower Granite Dam. The Connor et al. analysis, however, failed to find evidence for a flow-migration rate relation as fish passed downstream between Lower Granite and Little Goose dams probably because of limitations on their study. This does not suggest a downstream relationship does not exist, rather that different degrees of smoltification will result in different rates of migration and therefore, complicate such relationships.

Giorgi et al. (2002) reiterate a concern by several researchers that many environmental variables may be responsible for patterns of survival through the hydrosystem. Flow and spill are unlikely the only variables affecting survival; however, many of the variables of concern are a result of changes in flow. Turbidity and temperature, for example, have been suggested to be driving survival patterns, but these are often dependent on flow, flow is not dependent on turbidity and temperature. These factors may make flow/survival patterns more difficult to observe but they should not be used as evidence that flow is not an important driver to relationships that we do observe.

A large proportion of Snake River spring/summer chinook and steelhead have been removed from the river for transportation since Snake River dam construction, yet their subsequent survival may also be influenced by the environmental conditions (flow and spill in particular) experienced prior to collection and transportation (Budy et al. 2002; Mundy et al. 1994). Examples of mechanisms by which flow or water travel time may influence post-transport survival of smolts include effects of delayed migration on energetic condition (reduced lipids), exacerbated by stress at the collection projects, holding facilities and in transportation.

As with transportation and spill, considerations to the impacts of flow outside the hydrosystem, including delayed mortality to both transported fish and those that migrated in-river (Budy et al. 2002), must be taken into consideration. Flow may be important below Bonneville where fish and avian predators are most abundant and survival is not currently estimated as fish and avian predators are most abundant in this area. As stated above, smolts undergo dramatic physiological changes to cope with entry into the estuary and saltwater. Changes in flow can greatly affect the physiological timing of this transition. For example, Schreck and Stahl (1998) have documented that smolts that are stressed (from barging or migrating in-river) avoid entry into saltwater by remaining on the floating freshwater lens at the saltwater-freshwater interface. This forces smolts to the surface where they are susceptible to avian predation. Increased flows

out of the Columbia enhance mixing of freshwater and saltwater and aid migrating salmon into the transition to saltwater decreasing this delayed hydrosystem mortality. Through these mechanisms both transported and in-river fish can be greatly affected by the flow regime. How this and other factors in the hydrosystem affect survival back to adults is of prime importance. Giorgi et al. (2002) does not evaluate the impacts of flow on these other life stages but evidence can be found for this in NMFS white papers, and in previous fish and wildlife agency comments to the Council.

Methods of Travel time and Survival Data Analysis for Juvenile Steelhead and Chinook Springs Migrants

Travel time and survival

The juvenile migrants considered for these analyses represent groups for which travel time and survival was estimated for the entire Snake River (Lower Granite Dam to McNary Dam) reach using PIT tag technology. The first year that PIT tag data was available for survival estimation in the entire Lower Granite to McNary reach was 1995, however, not until 1998 when installation of full bypass PIT tag detection at John Day Dam was completed did we begin to obtain reliable estimation of survival to McNary Dam. Although survival studies using PIT tags were initiated as soon as the PIT tag detection units were installed at the projects, the reaches covered were limited in the early years. In 1993 survival studies could only be conducted between Lower Granite and Little Goose dams. This was expanded in 1994 to the Lower Granite to Lower Monumental river reach when PIT tag detectors were installed at additional projects. In 1995 to 1997, direct estimates of survival in the Lower Granite to McNary Dam reach were possible; however, due to limited detection capability at John Day Dam (detection of sampled fish from one gatewell slot out of 48) and moderate detection capability at Bonneville Dam due to operational spill levels at that facility, the resulting reach survival estimates had low precision. The detection limitations of the early years necessitated the extrapolation of the shorter river reach survival estimates to the longer reach (Lower Granite to McNary). It is now known that these earlier estimates using extrapolation resulted in a miss-representation of survival when applied to the longer reach. Consequently, we have chosen not to include these estimates in our analysis. Reliable estimation of survival to McNary Dam was not possible until installation of bypass detectors at John Day in 1998. For these reasons we have chosen to use survival estimate from 1998 to 2002 in creating the bivariate and multiple regression models. The above detection limitations below McNary Dam do not impact the quality of the travel time data from Lower Granite Dam to McNary Dam and therefore, travel time analyses use data from 1995 to 2002 for yearling chinook and 1996 to 2002 for steelhead. All juvenile yearling chinook and steelhead marked using PIT tags at hatcheries and fish traps above Lower Granite Dam and subsequently recaptured at the initial site, as well as those fish marked and released at Lower Granite Dam, were used in our analysis.

For the analyses pertaining to the Mid Columbia River, travel time and survival was estimated from Rock Island to McNary dams for releases of yearling chinook and steelhead marked and released at Rock Island Dam from 1998 to 2002. The Mid-Columbia fish used in our analysis were marked at Rock Island as part of the Fish Passage Center's Smolt Monitoring Program.

For the Snake River this study used all juvenile yearling chinook and steelhead marked using PIT tags at hatcheries and fish traps above Lower Granite Dam and subsequently recaptured at the initial site, as well as those fish marked and released at Lower Granite Dam. In the Mid Columbia the fish used were marked at Rock Island Dam as part of the Fish Passage Center's Smolt Monitoring Program. The accuracy and precision associated with any estimate of survival or travel time will be dependent on the number of fish in a release group (N) and the number of fish subsequently recaptured. The intent of the analysis was to relate the dependent variables (travel time and survival) to a series of independent environmental variables. As fish migrate through the hydrosystem the initial release group disperses over time making the description of an average environmental condition difficult. The best chance of describing the environmental variable for each group was to limit the time frame over which the variable was estimated before groups became too dispersed and to reduce the overlap among groups. Consequently, when grouping daily releases of PIT tagged groups together over longer periods of time to provide the most accurate and precise estimate, it is important to not group too large a time period to mask the effect of environmental variables. For smolts originating in the Snake River basin, travel time and survival estimates were developed for each weekly release block in the available years of data. Each year was divided into eight weekly periods for wild and hatchery yearling chinook and into six weekly periods for steelhead. For the Mid Columbia migrants, the season was divided into three two-week blocks for each year.

Smolt travel time is amount of time needed for juvenile migrants to transit the river system between any two points. For each temporal block, an estimate of median travel time was calculated from the smolts transiting the entire reach of interest.

Survival is estimated using the Cormack-Jolly-Seber (CJS) tag-recapture methodology. This method estimates survival components between each dam within the index reach having PIT tag detection equipment such as Little Goose, Lower Monumental, and McNary dams (additional detections at John Day and Bonneville dams downstream of McNary Dam also contribute to process of estimating survival in the upstream reaches. In the case of the Snake River reach, the survival estimate is the product of survival from Lower Granite Dam tailrace to Little Goose Dam tailrace, Little Goose Dam tailrace to Lower Monumental Dam tailrace, and Lower Monumental Dam tailrace to McNary Dam tailrace. In the case of the Mid-Columbia River reach, the survival estimate is the single estimate from Rock Island Dam tailrace to McNary Dam tailrace. The Snake River reach includes four reservoirs and dams and the Mid-Columbia River reach includes three reservoirs and dams.

Because the recovery of the PIT tags is dependent on being observed in a bypass system at downstream hydroprojects, the river and project operations exert considerable influence on the ability to obtain sufficient tag recoveries to obtain a valid estimate. Several criteria were employed to distinguish among the resulting estimates to assure their validity. Any temporal blocks which contained less than 300 smolts in the release group provided too few recoveries to

make valid estimates of survival. Consequently, no estimates of survival and travel time were made when less than 300 smolts were available. In addition, another criterion was applied to the estimates of survival. When the coefficient of variation (standard error divided by estimate) of any component survival estimate exceeded 0.25, the full reach survival estimate was excluded from the analysis. This check was made prior to multiplying the several component survival estimates to create a full reach survival estimate, as was the case in the Snake River basin. Whenever a component survival estimate was greater than 1, then the standard error divided by 1 was used as the threshold criteria. In the years 1998 to 2002, only one wild chinook, two hatchery chinook, and one steelhead temporal block needed to be excluded due to the minimum coefficient of variation criterion. In the Snake River reach, the final survival data set contained 66 estimates of survival for yearling chinook (hatchery and wild combined) and 26 estimates for steelhead. In the Mid Columbia, the final survival data set contained 13 estimates for yearling chinook and 15 estimates for steelhead. All survival estimates were accompanied with associated environmental variables.

Environmental Variables: Water transit time, spill proportion, and water temperature

Predictor variables of in-river survival were considered that are related to how flow or velocity may affect the survival of smolts migrating in-river through the hydro system in specific reaches of the Snake and Columbia rivers. The final set of predictor variables included a water velocity related variable, a spill related variable, and river temperature.

Water Transit Time

Previous analyses suggested that changes in flow produced changes in water velocity, which determined how quickly smolts migrated through the hydrosystem. The actual flow regime experienced by a group of migrating juvenile fish is difficult to quantify. Past analyses have used an index of flow through a specific reach for a period of time around the median passage dates of the migration or an average flow over the entire passage period. Because of the discrete relation between flow and water transit time (WTT) (also known as water particle travel time) and the implication of velocity as the important determining factor, the flow variable was quantified as the summation of water transit times for each reservoir incorporated in a reach (Figures 1 and 2 showing relation between WTT and average flow in the Snake River and McNary Dam reservoir).

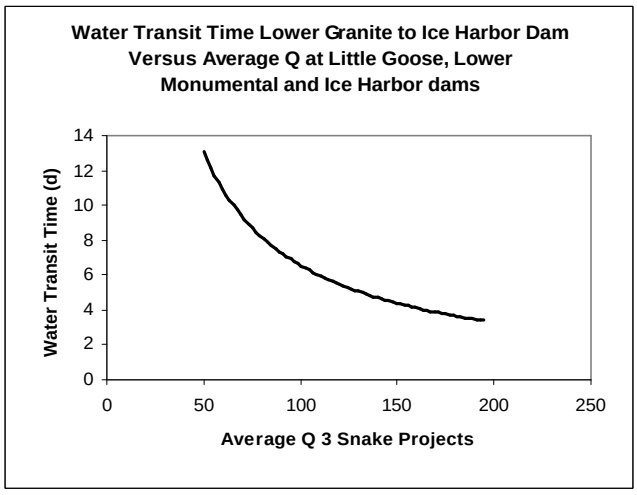

Figure 1. Relation between water transit time flow in Lower Snake River.

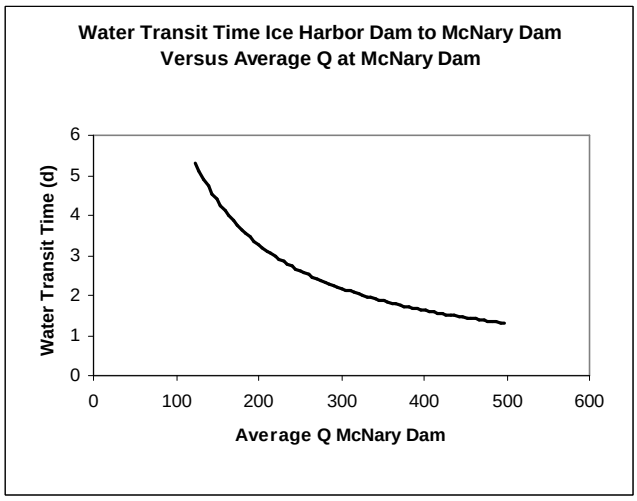

Figure 2. Relation between water transit and average time and average flow in McNary Pool.

The water transit time is the estimated amount of time required for a water particle to travel the fixed distance from the start of the reach to the end of the reach (WTT = distance / average water velocity). This fixed distance was 140 miles for the Snake River reach from Lower Granite Dam tailrace to McNary Dam tailrace and 161 miles for the Mid-Columbia River reach from Rock Island Dam tailrace to McNary Dam tailrace. The median travel time was estimated to each down stream project for each weekly block. The mid-date of release from LGR was used and to it was added median travel time for the release group to the downstream project. For each day, WTT is computed by dividing each reservoir volume by its corresponding daily average flow to determine the water particle transit time for that day. Reservoir volumes are obtained using COE tables and current reservoir elevations. For each reservoir, an average WTT is computed over a 7-day window of WTT's around the date of median passage of the fish of interest at the reservoir's downstream dam. These average WTT are then summed over the number of reservoirs in the reach of interest. The dates of median fish passage at each dam are obtained from PIT tagged smolts released from or passing during weekly blocks of time at Lower Granite Dam. This process is repeated for each weekly release group of PIT tagged smolts at Lower Granite Dam. Each weekly (7-day) release, starting April 1 for yearling chinook and April 17 for steelhead, was numbered sequentially from first through last week for each year to create a variable for week of entry into the reach.

Spill Proportion

For each reservoir and dam segment of the reach, survival may be viewed as the product of two components, a reservoir survival component and a dam passage component. In the dam passage component, survival may be viewed as the weighted average survival across each passage route, such as spillway route, turbine route, and bypass channel route (if present), where the weight is equal to the population of smolts using each route. Because the spill passage route has been shown to be the safest route of passage (except during periods of excessively high flows when gas may be a problem), increases in the amount of spill and numbers of fish passing through that route will have a direct effect on the reach survival estimate. Therefore, it is essential to include

a spill related variable in all multiple regression models, otherwise the effect of spill will be confounded within the parameter estimates of the other variables in the model (*i.e.*, a case of model misspecification). The variable representing spill at Little Goose, Lower Monumental, Ice Harbor, and McNary between April and June of 1998 and 2002 was the percentage of daily spill to total discharge. It was calculated using daily average spill and daily average total discharge at each project. Each daily percent Spill/Total Discharge was averaged over a seven-day passage window (centered around the median passage date) for each species and project. The average spill proportion is denoted as SPILLPROP in the subsequent text and tables.

Water Temperature

The dates of median fish passage at each dam are obtained from PIT tagged smolts released from or passing during weekly blocks of time at Lower Granite Dam. From these same 7-day windows around the dates of median smolt passage at each dam of interest, averages of river temperature are generated. Initially, a variable for the week of entry into the reach was considered, however, it was felt that the river temperature variable would already include the effect of this temporal variable in two ways. First, the general timing of the smolts at Lower Granite Dam is highly influence by river temperature. In years of warmer winters and earlier warming of the river, the smolts begin their migration earlier, whereas in years of cooler winter and later snowmelt, the smolts begin their migration later. Second, river temperature increase over time during the migration period, and so any effects of week of entry into the reach is already confounded within the river temperature variable. Therefore, week of entry into the reach was not used in the multiple regression analyses. The water temperature variable is denoted simply as TEMP in the subsequent text and tables.

Results of Travel Time Analysis

Snake River Reach: Lower Granite Dam to McNary Dam

Bivariate relations between smolt travel time and WTT were modeled using linear regression (Table 1). Relations for smolts originating above Lower Granite Dam and migrating between the tailrace of Lower Granite Dam and McNary Dam are shown for wild yearling chinook in Figure 3, hatchery yearling chinook in Figure 4, and steelhead (wild and hatchery) in Figure 5.

Table 1. Summary of linear regressions of median travel time versus water transit time for wild and hatchery yearling chinook and steelhead.

Group	Regression Equation	R^2
Wild Chinook	y = 1.245x + 0.8745	0.51
Hatchery Chinook	y = 1.107x + 2.3327	0.58
Steelhead	y = 1.250x - 1.2075	0.87

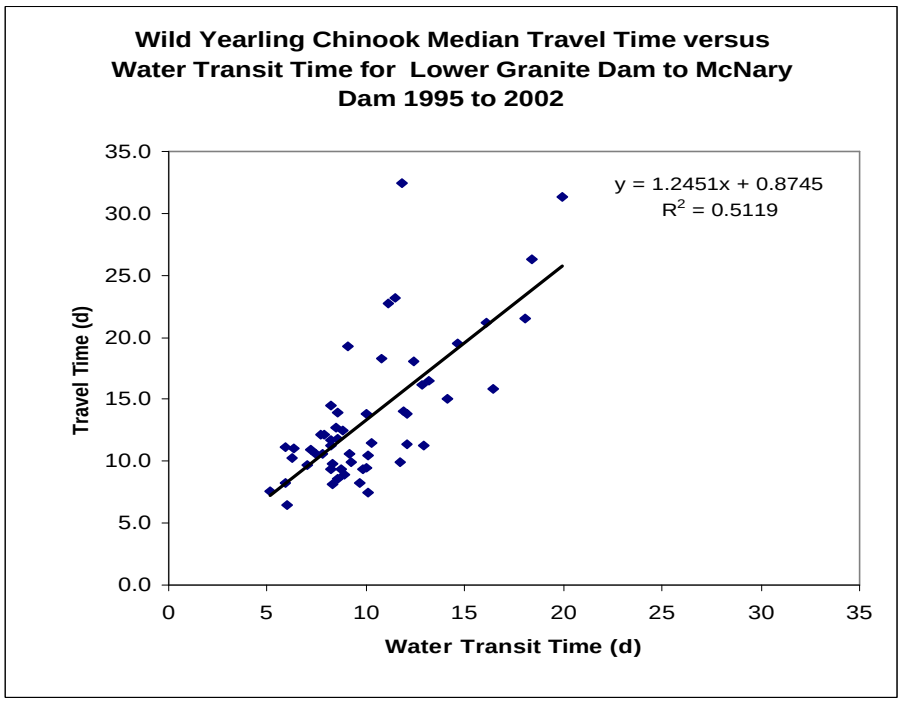

Figure 3. Wild yearling chinook travel time versus water transit time.

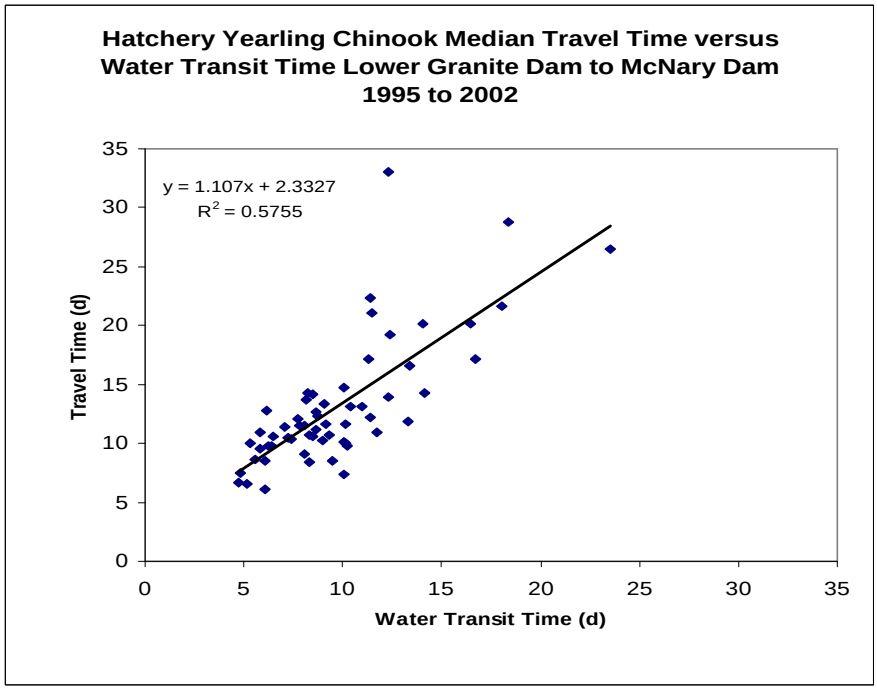

Figure 4. Hatchery yearling chinook travel time versus water transit time.

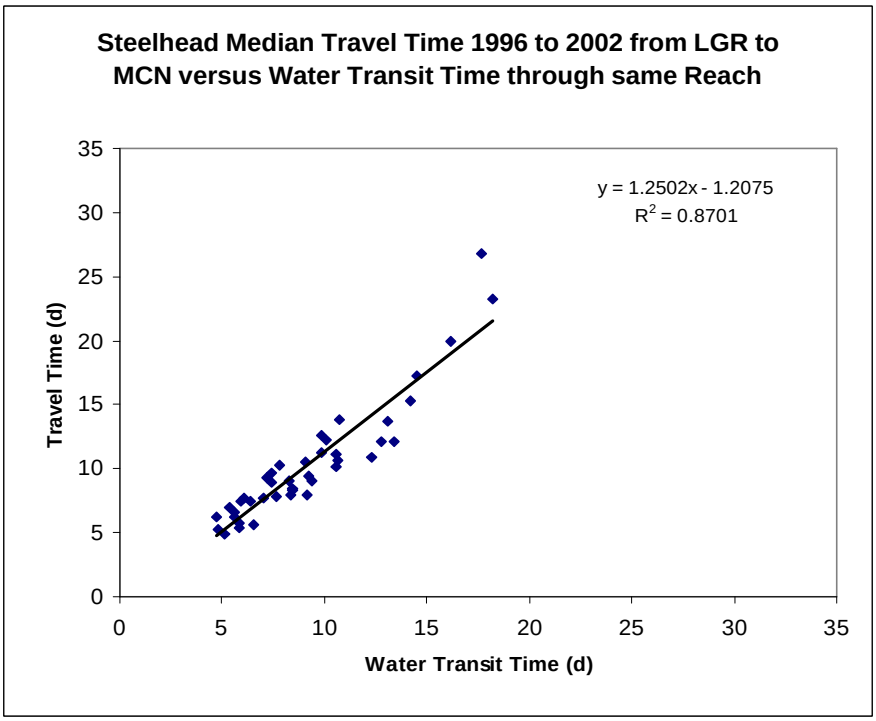

Figure 5. Steelhead travel time versus water transit time.

Mid-Columbia River Reach: Rock Island Dam to McNary Dam

Bivariate relations between smolt travel time and WTT were modeled using linear regression (Table 2). Relations for smolts originating above Rock Island Dam and migrating between the tailrace of Rock Island Dam and McNary Dam are shown for yearling chinook in Figure 6 and steelhead in Figure 7. For each species, the data is a mixture of wild and hatchery smolts.

Table 2. Summary of linear regressions of median travel time versus water transit time for wild and hatchery chinook and steelhead.

Group	Regression Equation	R^2
Yearling Chinook	y = 2.0797x - 1.8816	0.55
Steelhead	y = 1.8899x - 3.5432	0.93

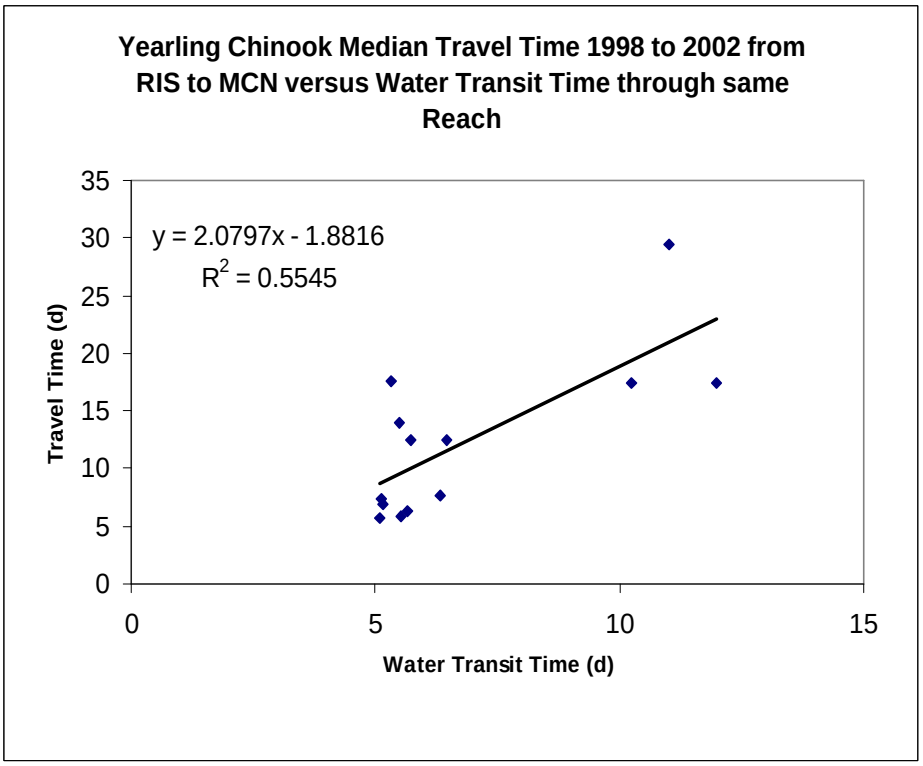

Figure 6. Yearling chinook travel time versus water transit time.

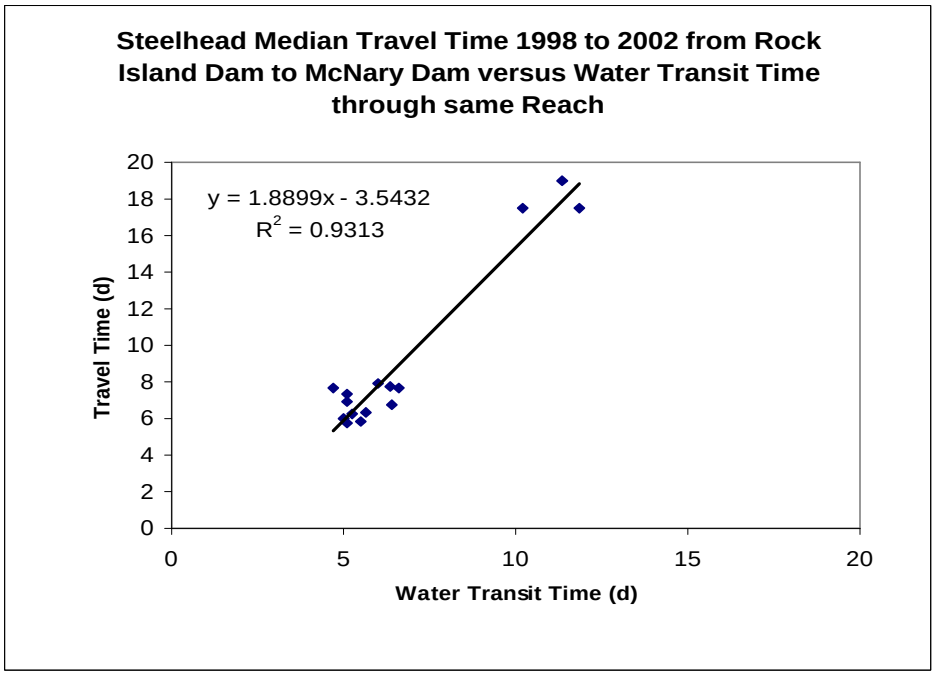

Figure 7. Steelhead travel time versus water transit time.

Results of Survival Analysis

Snake River Reach: Lower Granite Dam to McNary Dam

Survival Analysis for steelhead

The water transit time (WTT) and spill proportion (SPILLPROP) variables both had high correlation with the dependent variable survival (Table 3). Correlation between WTT and SPILLPROP was r = -0.81, a level low enough so that multicollinearity is not a problem. The square root of the variance-inflation factor, sqrt[1/(1-R^2)] provides a measure of the extent to which the standard error of the regression coefficients will be inflated due to high correlation between the predictor variables in a model. In the case of our model with WTT and SPILLPROP, the regression coefficient standard error will be inflated by a factor of approximately 1.7. Myers (1990) and Fox (1991) show that multicollinearity doesn't become a problem until the variance-inflation factor exceeds 10, which triples the standard error of the regression parameters. A plot of estimated survival of steelhead from the tailrace of Lower Granite Dam to the tailrace of McNary Dam relative to WTT shows a linear relation in Figure 8.

Table 3. Correlation matrix for variables related to steelhead.

	SURVIVAL	WTT	SPILLPROP
WTT	-0.914		
SPILLPROP	0.869	-0.809	
TEMP	-0.430	0.300	-0.464

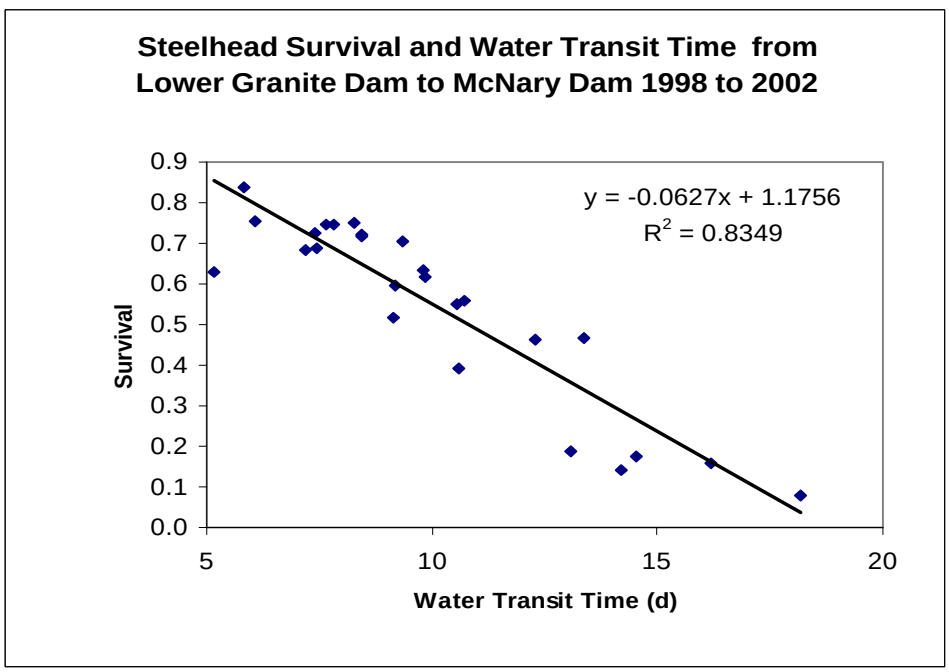

Figure 8. Steelhead survival versus water transit time

In the multiple regression analysis for steelhead, WTT and SPILLPROP were both significant variables in explaining variation in the dependent variable survival (Table 4). In the presence of these two variables, water temperature (TEMP) did not significantly explain any variation in survival. Since the various routes of passage, each with differential rates survival for passing fish, at a particular dam is an integral component of any reach "true" survival rate, it is encouraging to see a spill-related variable remain in the model. Any mechanistic model should always include the influence of spill, and it does so in the steelhead regression model. The joint model of WTT and SPILLPROP provides the best model for predicting steelhead survival in the Snake River reach.

Table 4. Multiple regression models for predicting survival of steelhead salmon in the Snake River from the tailrace of Lower Granite Dam to the tailrace of McNary Dam.

	Variable	Coefficient	SE	P	MSE	R^2
N = 26	Constant	0.79901	0.13203	0.00000	0.00639	0.87
	WTT	-0.04184	0.00831	0.00004		
	SPILLPROP	0.00527	0.00117	0.00508		

Survival for Yearling Chinook

Analysis of covariance was used to determine whether hatchery and wild chinook differed in survival response as a function of the predictor variables. Wild and hatchery chinook did not significantly differ with any of the predictor variables (Table 5). Plots of estimated survival of yearling chinook from the tailrace of Lower Granite Dam to the tailrace of McNary Dam relative to WTT shows similar linear relations for hatchery and wild fish (Figures 9a and 9b, respectively). All further analyses were conducted on the combined set of wild and hatchery chinook data.

Table 5. Analysis of Covariance comparison of hatchery and wild yearling chinook survival when all covariates are accounted for in the model.

	Variable	SS	df	MSE	F-ratio	P
N = 66	RearType	0.00191	1	0.00191	0.32314	0.57182
H = 32	WTT	0.05225	1	0.05225	8.81804	0.00426
W= 34	SPILLPROP	0.04096	1	0.04096	6.91232	0.01082
	TEMP	0.06892	1	0.06892	11.63241	0.00115
	Error		61	0.00593		

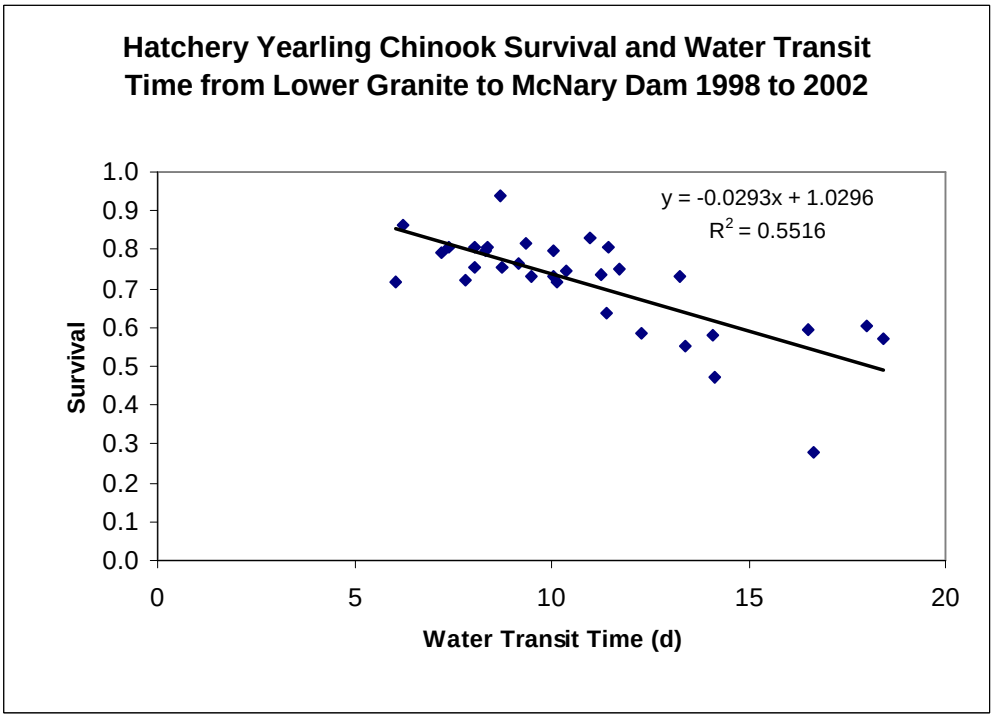

Figure 9a. Hatchery yearling chinook survival versus water transit time.

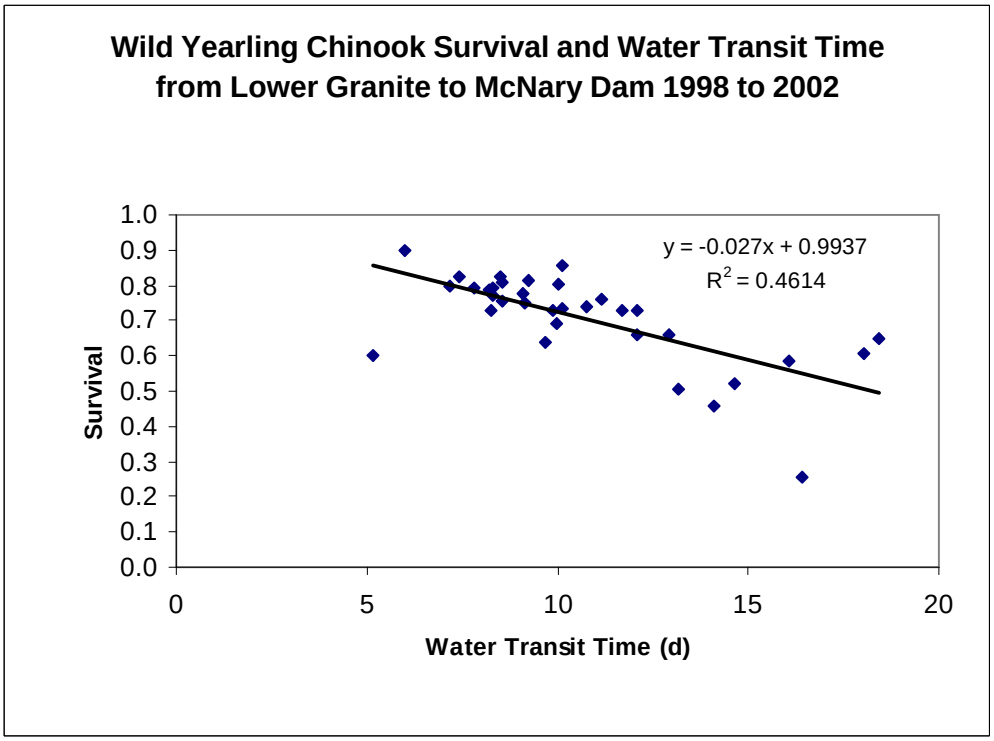

Figure 9b. Wild yearling chinook survival versus water transit time.

For the combined wild and hatchery yearling chinook, the WTT and SPILLPROP variables both had high correlation with the dependent variable survival (Table 6). As was observed with steelhead, the correlation between WTT and SPILLPROP for yearling chinook was r = -0.81, a level low enough so that multicollinearity is not a problem

Table 6. Correlation matrix for variables related to wild and hatchery yearling chinook salmon.

	SURVIVAL	WTT	SPILLPROP
WTT	-0.70898		
SPILLPROP	0.75498	-0.80546	
TEMP	-0.46136	0.16461	-0.34821

In the multiple regression analysis for yearling chinook, WTT and SPILLPROP were both significant variables in explaining variation in the dependent variable survival (Table 7). In the presence of these two variables, TEMP also was significant in explaining variation in survival. The joint model of WTT, SPILLPROP, and TEMP provides the best model for predicting yearling chinook survival in the Snake River reach.

Table 7. Multiple regression models for predicting survival of combined hatchery and wild yearling chinook salmon in the Snake River from the tailrace of Lower Granite Dam to the tailrace of McNary Dam.

	Variable	**Coefficient**	**SE**	**P**	**MSE**	**R^2**
N = 66	Constant	1.09264	0.13901	0.00000	0.0586	0.65
	WTT	-0.01497	0.00504	0.0042		
	SPILLPROP	0.00281	0.00106	0.01027		
	TEMP	-0.02624	0.00765	0.00109		

Mid-Columbia River Reach Rock Island Dam to McNary Dam

Survival Analysis for steelhead

For steelhead in the Mid-Columbia River reach, WTT had the highest correlation with the dependent variable survival, while both SPILLPROP and TEMP had similar moderate levels of correlation with survival (Table 8). The correlation between WTT and SPILLPROP for steelhead was r = -0.87, a level still low enough so that multicollinearity is not a problem. A plot of estimated survival of steelhead from the tailrace of Rock Island Dam to the tailrace of McNary Dam relative to WTT shows a linear relation in Figure 10.

Table 8. Correlation matrix for variables related to steelhead salmon.

	SURVIVAL	WTT	AVGSPILLPROP
WTT	-0.808		
AVGSPILLPROP	0.647	-0.870	
AVTEMP	-0.587	0.312	-0.193

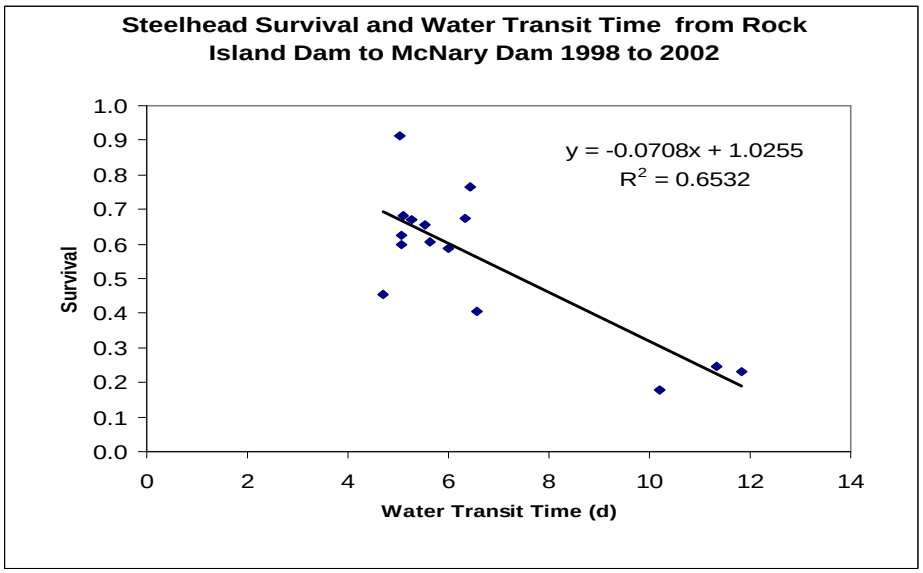

Figure 10. Steelhead survival versus water transit time.

In the multiple regression analysis for steelhead, WTT and TEMP were both significant variables in explaining variation in the dependent variable survival (Table 9). In the presence of these two variables, SPILLPROP did not significantly explain any variation in survival. Since the level of spill at Wanapam and Priest Rapids dams remained fairly constant over the years covered in the analysis, it is not surprising that SPILLPROP did not explain additional variation in survival. However, this finding does not reduce the intrinsic benefits of spill. Any mechanistic model should always include the influence of spill, and when it doesn't, the effect of spill becomes confounded within the coefficients of the other parameters in the model. For survival prediction purposes, the joint model of WTT and TEMP provides the best model for predicting steelhead survival from the tailrace of Rock Island Dam to the tailrace of McNary Dam.

Table 9. Multiple regression models for predicting survival of steelhead salmon in the Mid-Columbia River from the tailrace of Rock Island Dam to the tailrace of McNary Dam.

	Variable	Coefficient	SE	P	MSE	R^2
N = 15	Constant	1.6135	0.2425	0.00002	0.01136	0.74
	WTT	-0.06065	0.01256	0.00041		
	TEMP	-0.0553	0.02138	0.02383		

Survival for Yearling Chinook

For yearling chinook in the Mid-Columbia River reach, WTT and SPILLPROP had similar moderate correlation with the dependent variable survival (Table 10). The correlation between WTT and SPILLPROP for steelhead was r = -0.83, a level low enough so that multicollinearity is not a problem, but higher than observed for yearling chinook in the Snake River reach. A plot

of estimated survival of yearling chinook from the tailrace of Rock Island Dam to the tailrace of McNary Dam relative to WTT shows a linear relation in Figure 11.

Table 10. Correlation matrix for variables related to yearling chinook salmon.

	SURVIVAL	WTT	AVGSPILLPROP
WTT	-0.543		
AVGSPILLPROP	0.461	-0.828	
AVTEMP	-0.230	0.421	-0.211

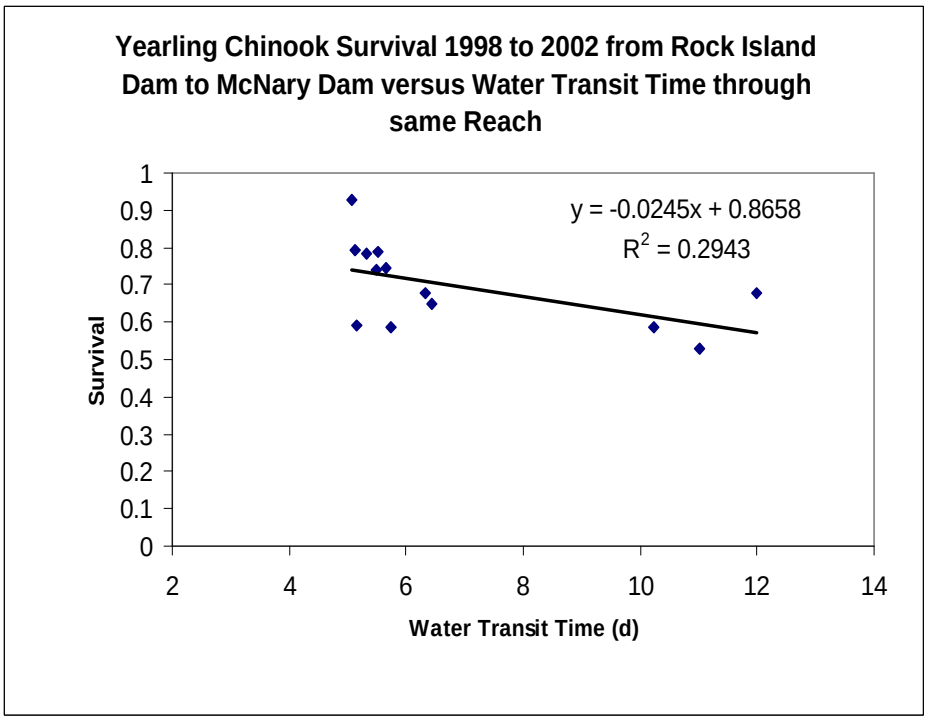

Figure 11. Yearling chinook survival versus water transit time.

In the multiple regression analysis for yearling chinook, only WTT was moderately significant in explaining variation in the dependent variable survival (Table 11). In the presence WTT, SPILLPROP did not significantly explain any variation in survival. Since the level of spill at Wanapam and Priest Rapids dams remained fairly constant over the years covered in the analysis, it is not surprising that SPILLPROP did not explain additional variation in survival. For survival prediction purposes, the simple bivariate model of WTT provides the best model for predicting yearling chinook survival from the tailrace of Rock Island Dam to the tailrace of McNary Dam.

Table 11. Multiple regression model for predicting survival of yearling chinook salmon in the Mid-Columbia River from the tailrace of Rock Island Dam to the tailrace of McNary Dam.

	Variable	Coefficient	SE	P	MSE	R^2
N = 13	Constant	0.86052	0.08282	0.00000	0.00956	0.23
	WTT	-0.02446	0.54250	0.05543		

Lower Columbia River Reach: McNary Dam to Bonneville Dam

Survival Analysis for steelhead

For combined hatchery and wild steelhead, the water transit time (WTT), spill proportion (SPILLPROP), and water temperature (TEMP) variables each had high correlation with the dependent variable survival (Table 12). Correlation between each pair of predictor variables was also very high, which lead to problems of multicollinearity when trying to include more than one predictor variable in the model. Thus, a model with only one predictor variable was obtained. Since WTT had the highest correlation with steelhead smolt survival, it entered into the bivariate model that explained the most variation in the dependent variable survival (Table 13). A plot of estimated survival of steelhead from the tailrace of Lower Granite Dam to the tailrace of McNary Dam relative to WTT shows a linear relation in Figure 12. Although a multiple regression model was not attainable, one must keep in mind that SPILLPROP still has a direct influence on the resulting magnitude of the survival estimate. This is because, as stated earlier, the survival of smolts that pass through the spill route is typically higher than any other passage route at a dam.

Table 12. Correlation matrix for variables related to steelhead.

	SURVIVAL	WTT	SPILLPROP
WTT	-0.959		
SPILLPROP	0.871	-0.969	
TEMP	-0.948	0.985	-0.930

Table 13. Bivariate regression model for predicting survival of steelhead salmon in the lower Columbia River from the tailrace of McNary Dam to the tailrace of Bonneville Dam.

	Variable	Coefficient	SE	P	MSE	R^2
N = 4	Constant	0.97747	0.10775	0.0119	0.00518	0.92
	WTT	-0.06481	0.01358	0.0412		

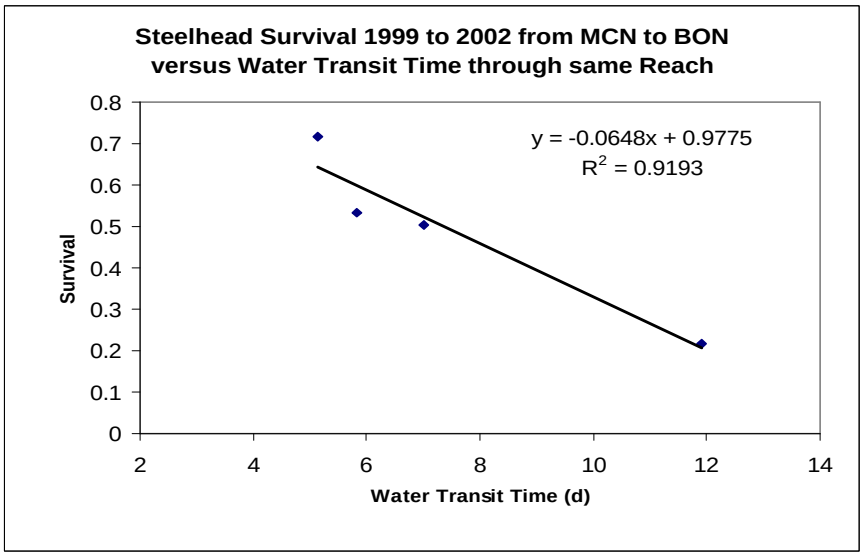

Figure 12. Steelhead survival versus water transit time

Survival for Yearling Chinook

For combined hatchery and wild yearling chinook, both WTT and SPILLPROP variables had high correlation with the dependent variable survival (Table 14), whereas AVTEMP had only a moderate correlation. Correlation between WTT and SPILLPROP was not high enough to create multicollinearity problems, but it was high enough to both variables from remaining together in a multiple regression model.

Table 14. Correlation matrix for variables related to yearling chinook salmon.

	SURVIVAL	WTT	SPILLPROP
WTT	-0.771		
SPILLPROP	0.870	-0.882	
TEMP	-0.433	0.431	-0.341

Since SPILLPROP had the highest correlation with yearling chinook smolt survival, it entered into the bivariate model that explained the most variation in the dependent variable survival (Table15). This is not to say that WTT is less important than SPILLPROP with regards to yearling chinook survival though. But it does show a major weakness in using regression techniques to pick the most important “causative” factors from the set of factors being considered in the modeling exercise. Although SPILLPROP has a direct influence on the resulting magnitude of the survival estimate, it level in the hydro system operation does not occur independent of the prevailing flows. Thus flows have a direct influence on WTT and so both variables must be considered as key elements affecting the inriver survival of smolts thorough the hydro system. A bivariate plot of estimated survival of yearling chinook from the tailrace of McNary Dam to the tailrace of Bonneville Dam is shown in Figure 13 relative to WTT and in Figure 14 relative to SPILLPROP.

Table 15. Bivariate regression models for predicting survival of yearling chinook salmon in the lower Columbia River from the tailrace of McNary Dam to the tailrace of Bonneville Dam.

	Variable	Coefficient	SE	P	MSE	R^2
N = 11	Constant	0.37096	0.05513	0.00009	0.00272	0.76
	SPILLPROP	0.87267	0.16458	0.00049		

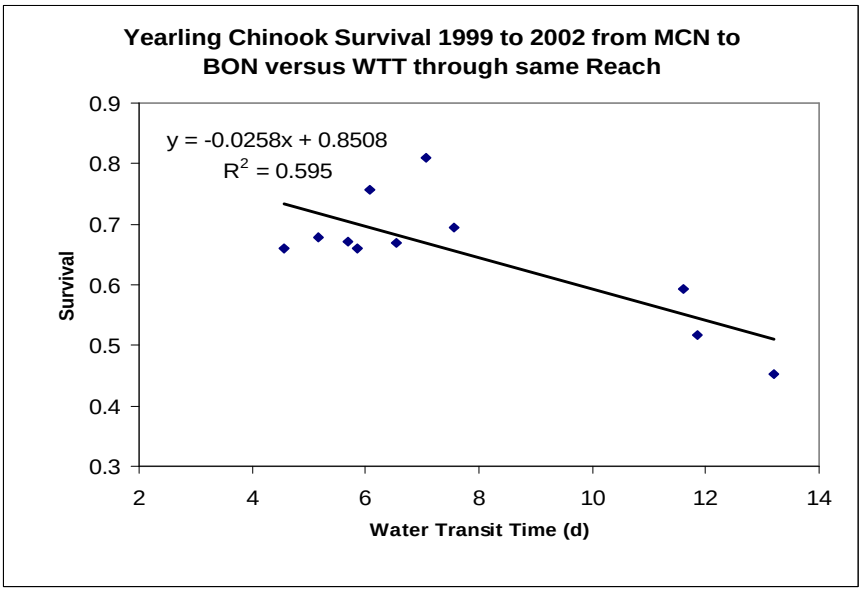

Figure 13. Yearling chinook survival versus water transit time.

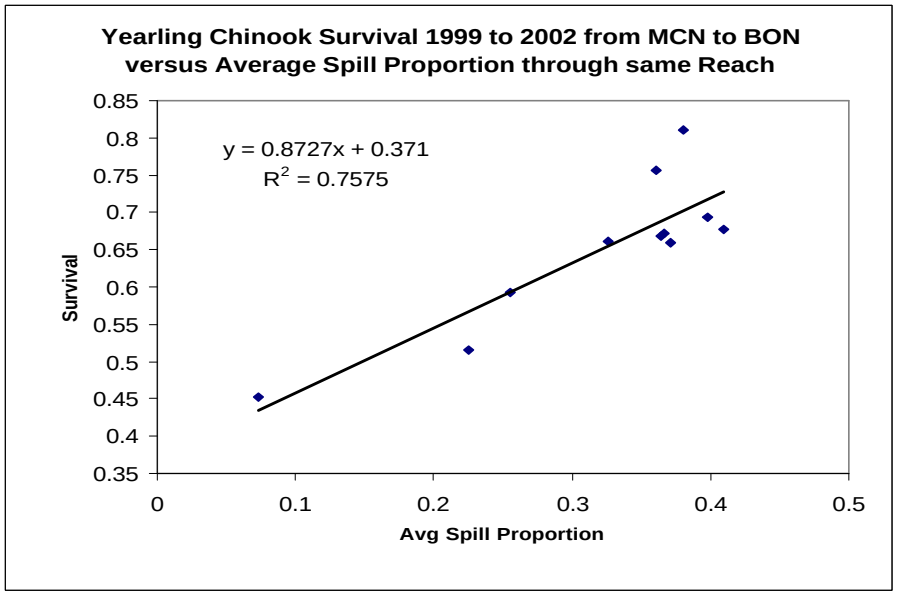

Figure 14. Yearling chinook survival versus average spill proportion.

Migration Timing in the Lower Columbia River as measured at John Day Dam

The population of juvenile salmon is not homogeneous throughout the entire migration season. Consequently, the concept of migration timing is extremely important in fish management. Some fish migrate in discrete time periods that may be significantly different from the timing displayed by the migration as a whole. We observed PIT tagged yearling chinook and steelhead at John Day Dam in 2001 and quantified their timing in the Lower Columbia River. Yearling chinook and steelhead stocks that originated in the Walla Walla, Umatilla and John Day rivers are the earliest stocks to pass John Day Dam in 2001. In 2001, the percent of PIT tagged yearling chinook from the John Day and Umatilla rivers detected at John Day Dam in April was approximately 53% and 13%, respectively (Table 16), whereas virtually no PIT tagged yearling chinook from the Snake and Mid-Columbia River basins were detected until May. The percent of PIT tagged steelhead from the John Day and Umatilla rivers detected at John Day Dam in April was approximately 31% and 11%, respectively (Table 17), and again virtually no PIT tagged steelhead from the Snake and Mid-Columbia River basins were detected until May.

Table 16. Proportion of PIT tagged yearling chinook detected at John Day Dam over specific periods of the 2001 migration season.

Dates of PIT tag detections at John Day Dam	Snake R basin	Mid-Columbia R basin at/above Rock Island Dam[1]	Yakima R basin	Umatilla R basin	John Day R basin
Total detections	14,086	2,091	4,041	1,291	1,743
3/30 – 4/30	0.0002	0.0000	0.0084	0.1332	0.5295
5/1 – 5/24	0.3369	0.1836	0.3606	0.7854	0.4509
5/25 – 6/15	0.5422	0.6738	0.5048	0.0736	0.0132
6/16 – 9/15	0.1207	0.1425	0.1262	0.0077	0.0063

[1] PIT tagged hatchery chinook released on alternating days at Rock Island & Rocky Reach dams in large numbers for specific studies were omitted because they do not represent the timing of the run-of-the-river fish.

Table 17. Proportion of PIT tagged steelhead detected at John Day Dam over specific periods of the 2001 migration season.

Dates of PIT tag detections at John Day Dam	Snake R basin	Mid-Columbia R basin at/above Rock Island Dam	Walla Walla R basin	Umatilla R basin	John Day R basin
Total detections	440	59	23	1,005	97
3/30 – 4/30	0.0045	0.0000	0.0000	0.1124	0.3093
5/1 – 5/24	0.4841	0.1525	0.8696	0.7532	0.6082
5/25 – 6/15	0.3886	0.5254	0.0870	0.1085	0.0825
6/16 – 9/15	0.1227	0.3220	0.0435	0.0259	0.0000

Rate of Seaward Movement of Subyearling Fall Chinook Summer Migrants Measured from Release in the Free-flowing Snake River to Passage Lower Granite Dam

Fall Chinook Rate of Seaward Movement Methods

From 1992 to 2001, U.S. Fish and Wildlife Service personnel used a beach seine to capture juvenile fall chinook salmon in the free-flowing Snake River (Connor et al. In press a). Sampling typically started in April soon after fry began emerging from the gravel. Sampling was conducted at permanent stations 1 d/week in the upper reach of the Snake River, and 2 d/week in the lower reach. Supplemental sampling was conducted 1 or 2 d/week for three consecutive weeks at additional stations within each reach once the majority of fish were at least 60-mm fork length. Sampling was discontinued in June or July when the majority of fish had moved into Lower Granite Reservoir. Passive integrated transponder tags were inserted into fall chinook salmon 60-mm fork length and longer. Data were pooled the data across reaches and years (1992-2001) to increase the range of the predictor variables (Berggren and Filardo 1993; Giorgi et al. 1997).

Tagged fish were released at the collection site after a 15-min recovery period. Some of the PIT-tagged fish were detected after they passed into the fish bypass systems of Lower Granite Dam. Rate of seaward movement for PIT-tagged fall chinook passing downstream from initial tagging sites to Lower Granite Dam was calculated as the distance traveled to Lower Granite Dam (located 173 km from the Snake River mouth) divided by travel time to Lower Granite Dam.

The predictor variables analyzed included: flow, the mean stream discharge (m^3/s) measured by U. S. Army Corps of Engineers personnel at Lower Granite Dam between initial tagging of a PIT-tagged fall chinook salmon and its detection at Lower Granite Dam; temperature, the mean temperature (^oC) measured by U. S. Army Corps of Engineers personnel in the forebay of Lower Granite Dam between initial tagging and detection at Lower Granite Dam; tagging date, day of year a fish was initially tagged; fork length, fork length (mm) measured on at initial tagging; and, riverine distance, the distance (km) traveled in the free-flowing Snake River before entering Lower Granite Reservoir.

Rate of seaward movement was natural-log-transformed to improve linearity and remedy heteroscedasticity of residuals, and bivariate and multiple regression models were fit from every possible combination of predictor variables. The slope coefficients of each predictor variable in every model were examined for sign change, and for inflated standard errors (hence, failure to reject H_o: $B = 0$). Sign changes and large standard errors are indications of problematic multicollinearity (Dielman 1996). A Pearson correlation matrix was calculated to examine the level of collinearity between each factor. Models with problematic multicollinearity, or that included factors with non-significant ($P > 0.05$) slope coefficients, were removed from further analysis. Fit was compared among the remaining regression models based on the coefficient of determination (R^2). The three regression models that had the highest R^2 values were reported.

Residual plots were made for flow and temperature as described for flow in the following example. Natural-log-transformed rate of seaward movement was regressed against fork length and riverine distance. The residuals from this regression were then plotted against flow. A line

was then fit to the residuals by regressing them against flow. The resulting residual plots provided a better graphical representation of the relation between flow and rate of seaward movement because the variability in downstream migration rate attributable to fork length and riverine distance had been removed.

Fall Chinook Rate of Seaward Movement Results

A total of 2,808 observations were available (years 1992-2001) to describe the factors affecting rate of seaward movement of PIT-tagged fall chinook salmon from initial tagging to detection at Lower Granite Dam. After pooling the data across reaches and running every possible regression model, the slope coefficient for flow changed from being positive to negative when flow and temperature were entered into the same regression models. The correlation coefficient for the relation between flow and temperature was $r = -0.77$ ($P < 0.0001$). The slope coefficient for tagging date changed from being negative to positive when tagging date and temperature were entered in the same regression models. The correlation coefficient for the relation between tagging date and temperature was $r = 0.60$ ($P < 0.0001$). All models containing both flow and temperature, and tagging date and temperature, were removed from the analysis because of problematic multicollinearity.

The regression model with the best fit included the predictor variables temperature, fork length and riverine distance (Table 18). The slope coefficients for each of the three factors differed significantly from zero, and together the three factors explained 73% of the variability observed in natural-log-transformed rate of seaward movement (Table 18). Natural-log-transformed rate of seaward movement generally decreased as temperature increased, and increased as fork length and riverine distance increased, as shown by the sign and *P* values of the slope coefficients (Table 18). The slope in the residual plot indicates that rate of seaward movement decreased as temperature increased throughout the range of 9 to 21°C (Figure 15).

The regression model that had the second-best fit included the factors flow, fork length, and riverine distance (Table 18). Flow, fork length, and riverine distance explained 66% of the variability observed in natural-log-transformed rate of seaward movement. Natural-log-transformed rate of seaward movement generally increased with increases in each of the three factors based on the slope coefficients, all of which differed significantly from zero (Table 18). The slope in the residual plot shows that rate of seaward movement increased as flow increased over the entire range of observed flows (Figure 15).

The regression model that had the third-best fit included the factors tagging date, fork length, and riverine distance (Table 18). Natural-log-transformed rate of seaward movement generally decreased with increases in tagging date, and increased as fork length and riverine distance increased, as shown by the signs and *P* values of the slope coefficients (Table 18). Together, these three factors explained 58% of the variability observed in natural-log-transformed rate of seaward movement (Table 18).

Table 18. Results from multiple regression models fit to describe rate of seaward movement of PIT-tagged wild subyearling fall chinook salmon from initial tagging in the Snake River and detection at Lower Granite Dam, 1992 to 2001.

Variable	coefficient	SE	t value	Probability	R^2	*P*
Constant	0.81598	0.07490	10.89	≤ 0.0001	0.726	≤ 0.0001
Temperature	- 0.15190	0.00382	- 39.73	≤ 0.0001		
Fl	0.02773	0.00060	46.16	≤ 0.0001		
Km	0.00798	0.00018	44.42	≤ 0.0001		
Constant	- 2.07197	0.05627	- 36.82	≤ 0.0001	0.659	≤ 0.0001
Flow	0.00024	0.00001	26.73	≤ 0.0001		
Fl	0.02498	0.00066	37.66	≤ 0.0001		
Km	0.00876	0.00020	43.88	≤ 0.0001		
Constant	-1.17620	0.10755	-10.94	≤ 0.0001	0.575	≤ 0.0001
Date	-0.00304	0.00083	-3.68	0.0002		
Fl	0.02568	0.00090	28.64	≤ 0.0001		
Km	0.01061	0.00022	49.56	≤ 0.0001		

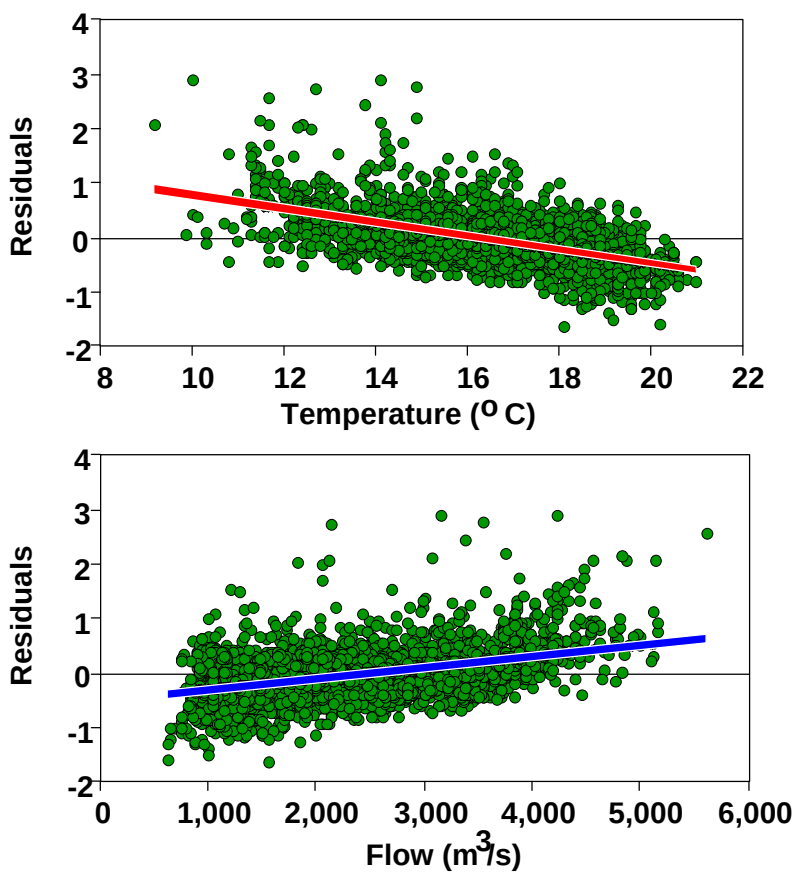

Figure 15. Wild subyearling chinook rate of seaward movement versus temperature and flow.

Fall Chinook Rate of Seaward Movement Discussion and Conclusions

Though the regression model that predicted natural-log-transformed rate of seaward movement from the predictor variables temperature, fork length, and riverine distance had the best fit of all models tested, Connor et al. (In press a) concluded that it is unrealistic to expect an inverse relation between temperature and rate of seaward movement over the entire range of temperatures studied (9 to 21°C). Fall chinook salmon that are exposed to mean temperatures of 20°C and above before they become smolts would be expected to move seaward at slower rates than those that experience cooler temperatures because of a reduced likelihood of successful smoltification (e.g., Marine 1997). However, rate of seaward movement should have increased as temperature increased up to at least 17°C as a result of increased growth and normal patterns of smolt development (Banks et al. 1971; Boeuf 1993; Marine et al. 1997; Connor and Burge in press). Connor et al. (In press a) concluded that the decrease in rate of seaward movement as temperature increased to 17°C was most likely caused by the accompanying decreases in flow.

The regression model with the second-best fit included the predictor variables flow, fork length, and riverine distance. This regression model showed that the relation between rate of seaward movement and flow was positive consistent with the results of other studies (Berggren and Filardo 1993; Tiffan et al. 2000). Higher rates of seaward movement at higher flows (or vice versa) can be explained by the relation between discharge and water velocity. Water velocity in reservoirs is proportional to the ratio of discharge to channel volume. Since the length of Lower Granite Reservoir presumably changes little over time, the change in volume can be described by changes in pool elevation. Lower Granite Reservoir was held at minimum operating pool elevations ranging from approximately 223 to 224 m above mean sea level during the summer (U. S. Army Corps of Engineers, unpublished data). Therefore, the flow values Connor et al. (In press a) used in their regression modeling were proportional to velocities in Lower Granite Reservoir upstream of Lower Granite Dam forebay suggesting that rate of seaward movement increased as velocity increased. These results support a flow-migration rate relation.

Rate of seaward movement from release in the Snake River to passage at Lower Granite Dam decreased as tagging date increased according to the results of the regression model with the third-best fit. Tagging date (a.k.a., release date) is used as a surrogate for time-based physiological, behavioral, and environmental processes when describing seaward movement of juvenile anadromous salmonids (e.g., Berggren and Filardo 1993; Giorgi et al. 1997; Connor et al. 2000). There was no significant tagging date effect when flow and tagging date were entered into the same regression model. Problems with multicollinearity were encountered when tagging date and temperature were entered into the same regression model. In the Connor et al. In press a) analyses, tagging date apparently functioned as a surrogate for flow and temperature. To a lesser extent, increases in date also reflected the decreased potential for successful smoltification of fish initially tagged late in the seining season.

Connor et al. (In press a) concluded that the increases in flow and decreases in temperature resulting from summer flow augmentation increases the rate of seaward movement of fall chinook salmon in Lower Granite Reservoir (where fish spend prolonged periods of time) provided that augmentation occurs when the fish have moved offshore in the free-flowing river and are behaviorally disposed to being displaced downstream. The regression model that

included flow predicts an increase in rate of seaward movement of approximately 0.1 km/d with each increase of 100 m^3/s in flow when fork length and riverine distance are held at 74 mm and 40 km (the overall 1992-2001 medians). At temperatures above 17^oC, the regression model that included temperature predicts an increase in rate of seaward movement of approximately 0.2 km/d with each decrease of 1^oC when fork length and riverine distance are held at 74 mm and 40 km. Increasing the rate of seaward movement by 0.1 to 0.2 km reduces travel time to Lower Granite Dam by 1 to 5 d (Connor 2001).

Survival of Wild Subyearling Fall Chinook Summer Migrants Measured from Release in the Free-flowing Snake River to Passage at Lower Granite Dam and Passage Timing at the Dam

Fall Chinook Survival Methods

Data collected on fall chinook salmon from 1998 to 2000 were analyzed. Data for these years were selected because sample sizes of tagged fall chinook salmon were large, and tagged fish were not handled as they passed Lower Granite Dam. Field personnel captured and PIT tagged fall chinook salmon by using a beach seine as described for analyses on rate of seaward movement . After detection at Lower Granite Dam, the PIT-tagged smolts were routed through flumes back to the river. Smolts then had to pass seven more dams to reach the Pacific Ocean. Little Goose, Lower Monumental, McNary, John Day, and Bonneville dams were also equipped with monitoring systems that recorded the passage of PIT-tagged smolts that used the bypass systems, and then routed the bypassed fish back to the river.

The first step in the analysis was to divide the annual samples of PIT-tagged fall chinook salmon into four sequential within-year release groups referred to as cohorts. The annual samples into cohorts based on estimated fry emergence dates. Fry emergence date was estimated for each fish in two steps. First, the number of days since each PIT-tagged fish emerged from the gravel was calculated by subtracting 36 mm from its fork length measured at initial capture, and then dividing by the daily growth rate observed for recaptured PIT-tagged fish (range 0.9 to 1.3 mm/d; Connor and Burge in press). The 36-mm fork length for newly emergent fry was the mean of the observed minimum fork lengths. Second, emergence date was estimated for each fish by subtracting the estimated number of days since emergence from its date of initial capture, tagging, and release. The data in ascending order by estimated fry emergence date, and then divided it into four cohorts of approximately equal numbers of fish. The single release-recapture model (Cormack 1964; Skalski et al. 1998) was used to estimate survival probability to the tailrace of Lower Granite Dam for each cohort. Three assumption tests described by Burnham et al. (1987) and Skalski et al. (1998) were applied to insure that the single release-recapture model fit the data.

Cohort survival was the dependent variable for the analysis. The predictor variables were: tagging date, median day of year fish from each cohort were captured, tagged, and released; fork length, mean fork length (mm) at capture, tagging, and release for the fish of each cohort; flow, a flow (m^3/s) exposure index calculated as the mean flow measured at Lower Granite Dam by U.S. Army Corps of Engineers personnel during the period when the majority of smolts from

each cohort passed the dam; and temperature, a water temperature (^{o}C) exposure index calculated as the mean temperature measured in the tailrace of Lower Granite Dam by U.S. Army Corps of Engineers personnel during the period when the majority of smolts from each cohort passed the dam.

To determine when the majority of smolts passed Lower Granite Dam, the PIT-tag detection data were used to calculate a passage date distribution for each cohort including the 25th percentile, median, 75th percentile, range of non-outliers, and mild outliers. The date cutoffs for mild outliers were calculated as the 25th percentile minus the inter-quartile range multiplied by 1.5 (i.e., the lower fence; Ott 1993), and the 75th percentile plus the inter-quartile range multiplied by 1.5 (i.e., the upper fence; Ott 1993). All but the mild outliers were considered to be in the majority. See Connor et al . In press b for more details on calculating flow and temperature exposure indices.

A Pearson correlation coefficient (r) was calculated to test for collinearity among the predictor variables. Predictor variables that were correlated ($r \geq 0.6$; $P \leq 0.05$) were not entered into the same model. Multiple regression models were fit from every combination of non-collinear predictor variables. Fit was compared among models based on Mallow's Cp scores (Dielman 1996), Akaike's information criteria (AIC; Akaike 1973), and the coefficient of determination (R^2). The final (i.e., best) regression model had a Mallow's Cp score similar to the number of parameters, the lowest AIC value, the highest R^2 value, and predictor variables with slope coefficients that differed significantly ($t \geq 2.0$; $P \leq 0.05$) from zero. Only the top three models are reported.

We made residual plots for each predictor variable in the final regression model as described for flow in the following example. Estimated survival was regressed against temperature. The residuals from this regression were then plotted against flow. A line was then fit to the residuals by regressing them against flow. The resulting residual plots provided a better graphical representation of the relation between survival and flow because the variability in survival attributable to temperature had been removed.

We assessed the effect of summer flow augmentation on cohort survival to the tailrace of Lower Granite Dam by comparing two predictions. First, we predicted cohort survival to the tailrace of Lower Granite Dam by entering the observed mean flow and water temperature exposure indices for each cohort into the final regression model. Cohort survival was then predicted a second time by entering mean flow and water temperature exposure indices into the final regression model that were recalculated to remove effects of summer flow augmentation.

The flow exposure index was recalculated after subtracting the daily volume of water released for summer flow augmentation. The water temperature exposure index was recalculated using temperatures that were simulated for the tailrace of Lower Granite Dam under the flow conditions had the summer flow augmentation not been implemented. Water temperatures were simulated using a one-dimensional heat budget model developed for the Snake River by the U.S. Environmental Protection Agency (Yearsley et al. 2001). Past model validation showed that daily mean water temperatures simulated for July and August were within an average of 1.1^{o}C of those observed (Yearsley et al. 2001).

Fall Chinook Survival and Passage Results

During the 3 years, 5,030 fall chinook salmon were captured, PIT tagged, and released along the free-flowing Snake River. Annual sample sizes of PIT-tagged fall chinook salmon were 2,060 in 1998, 1,761 in 1999, and 1,209 in 2000. The number of fall chinook salmon in the resulting 12 cohorts ranged from 302 to 515 (Table 19). Emergence dates, tagging dates, fork lengths, and water temperature exposure indices generally increased from cohort 1 to 4 (Table 19). Flow exposure indices and survival estimates decreased from cohort 1 to 4 (Table 19).

Tagging date and fork length were negatively correlated (N = 12; r = -0.76; P = 0.004). Therefore, tagging date and fork length were not entered into the same multiple regression model. Fork length and flow (N = 12; r = 0.47; P = 0.12), fork length and temperature (N = 12; r = -0.54; P = 0.07), and flow and temperature (N = 12; r = -0.45; P = 0.15) were non-collinear.

The model that predicted cohort survival from flow and temperature had a Mallow's Cp score one less than the number of parameters, the lowest AIC value, and an R^2 of 0.92 (Table 20). The models that included fork length or tagging date had Mallow's Cp scores that equaled the number of parameters, relatively low AIC values, and R^2 values of 0.92 (Table 20), but the slope coefficient for fork length (t = 0.05; P = 0.96) and tagging date (t = 0.07; P = 0.94) did not significantly differ from zero.

Table 19. Emergence dates, predictor variables, and estimates of survival probability (%±SE) to the tailrace of Lower Granite Dam for each cohort of wild subyearling fall chinook salmon, 1998 to 2000. Predictor variables: Tagging date, median day of year of tagging; Fl, mean fork length (mm) at tagging; Flow, a flow (m^3/s) exposure index calculated as the mean flow measured at Lower Granite Dam during the period when the majority of smolts passed the dam; and Temperature, a water temperature (^oC) exposure index calculated as the mean temperature measured in the tailrace of Lower Granite Dam during the period when the majority of smolts passed the dam.

Cohort	*N*	Emergence date	Tagging date	Fl	Flow	Temperature	Survival
				1998			
1	515	7 April	140	80	2,344	17.6	70.8±2.9
2	515	15 April	141	75	2,021	18.7	66.1±3.3
3	515	23 April	153	73	1,898	19.0	52.8±3.1
4	515	7 May	167	70	1,299	19.8	35.6±2.9
				1999			
1	441	20 April	147	80	2,378	16.3	87.7±4.6
2	440	30 April	153[A]	77	1,963	17.1	77.0±3.8
3	440	5 May	152[A]	70	2,116	16.7	81.2±5.8
4	440	13 May	167	68	1,353	18.3	36.4±3.5
				2000			
1	303	6 April	130	77	1,510	16.7	57.1±4.1
2	302	15 April	144	77	1,296	17.6	53.4±4.2
3	302	22 April	146	77	1,274	17.8	44.4±3.6
4	302	29 April	158	71	859	18.5	35.7±4.3

[A] Fish from cohort 2 emerged earlier than fish of cohort 3, but they were initially captured, tagged, and released later than fish of cohort 3.

Table 20. Mallow's Cp scores, Akaikes information criteria (AIC), and coefficients of determination (R^2) used to compare the fit of multiple regression models describing the survival of cohorts of wild subyearling fall chinook salmon from tagging in the Snake River to the tailrace of Lower Granite Dam, 1998 to 2000. Predictor variables: Tagging date, median day of year of tagging; Fl, mean fork length (mm) at tagging; Flow, a flow (m^3/s) exposure index calculated as the mean flow measured at Lower Granite Dam during the period when the majority of smolts passed the dam; and Temperature = a water temperature (^oC) exposure index calculated as the mean temperature measured in the tailrace of Lower Granite Dam during the period when the majority of smolts passed the dam.

C(p)	AIC	R^2	Variables in model
2	44	0.92	Flow, Temperature
4	46	0.92	Fl, Flow, Temperature
4	46	0.92	Tagging date, Flow, Temperature

The final multiple regression model was: Cohort survival = 140.82753 + 0.02648 Flow -7.14437 Temperature. The final model was significant (N = 12; $P \leq 0.0001$) as were the coefficients for flow (t = 6.81; $P \leq 0.0001$) and temperature (t = - 3.96; P = 0.003). Flow and temperature explained 92% of the observed variability in cohort survival to the tailrace of Lower Granite Dam. Cohort survival generally increased as flow increased, and decreased as temperature increased (Figure 16).

The majority of fall chinook salmon passage occurs in July and August (Figures 17-19). Water releases for summer flow augmentation in 1998, 1999, and 2000 were generally timed to coincide with the passage of smolts from mid-July through August at Lower Granite Dam (Figures 17-19). Therefore, these later migrants were usually predicted to accrue greater survival benefits than the earlier migrants cohorts (Table 21). For all cohorts, estimated survival to the tailrace of Lower Granite Dam was predicted to be higher when summer flow augmentation was implemented than when it was not implemented (Table 21; Figure 20). Notably, eliminating flow augmentation in early July and August would likely decrease survival of a large portion of the smolts.

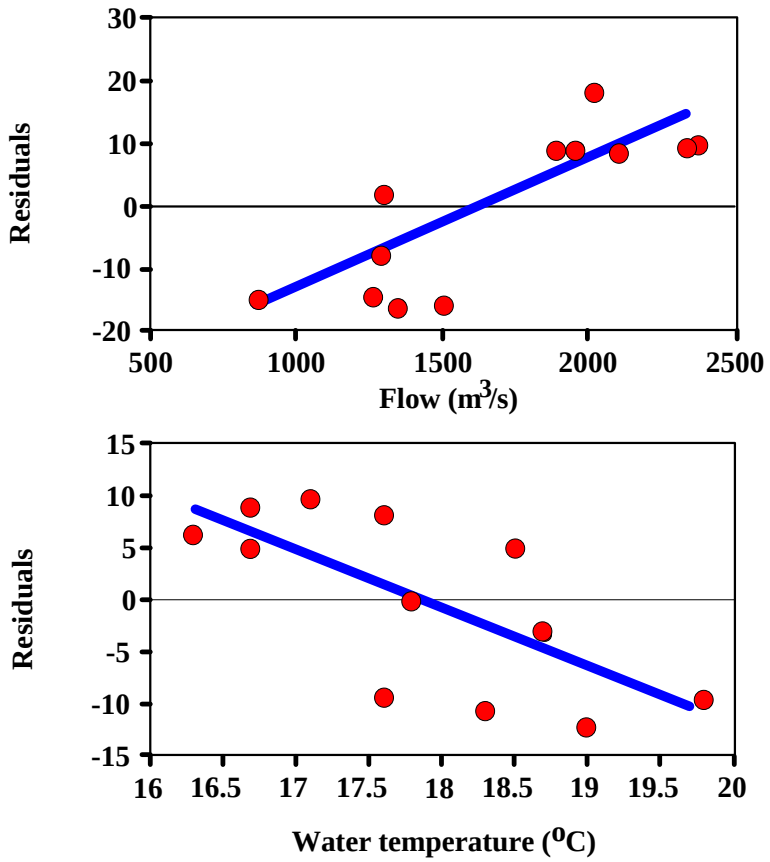

Figure 16. Residuals plots for flow and temperature. Residuals are from ordinary least-squares multiple regression models fit to predict cohort survival from the predictor variables that is not on the X-axis. The line in each plot was predicted by regressing the residuals against the predictor variable on the X-axis.

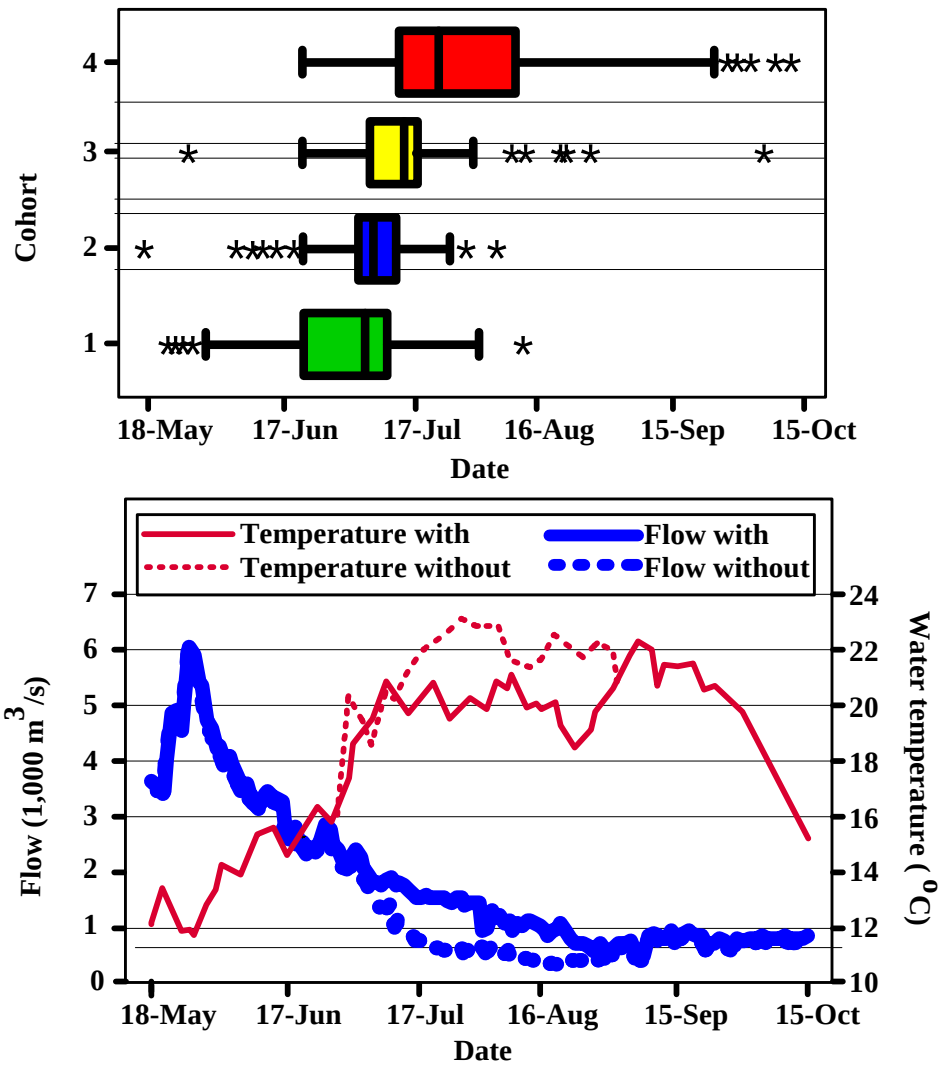

Figure 17. Box plots showing passage timing at Lower Granite Dam for PIT-tagged wild subyearling fall chinook salmon from each of four cohorts in 1998 (top), and the mean daily flows and water temperatures observed in Lower Granite Reservoir when flow was augmented (with) compared to those that may have occurred if flows had not been augmented (without; bottom).

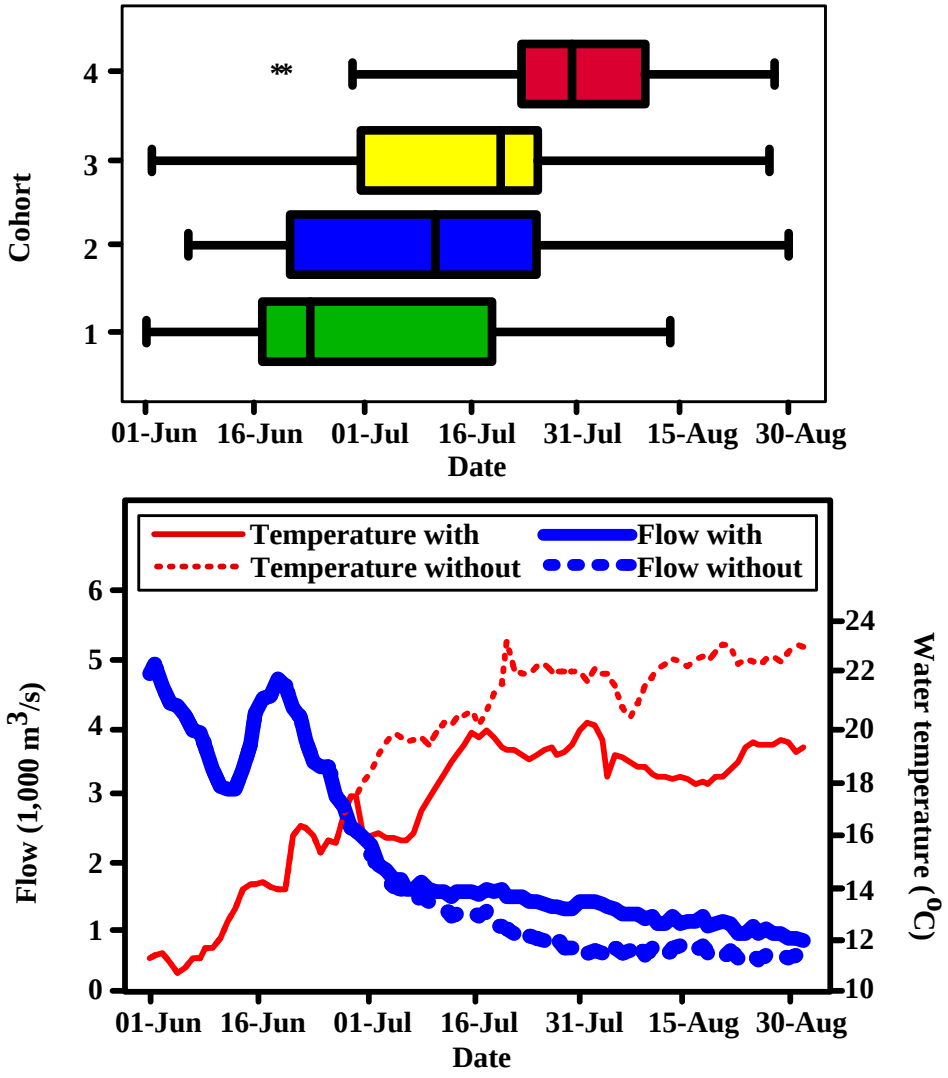

Figure 18. Box plots showing passage timing at Lower Granite Dam for PIT-tagged wild subyearling fall chinook salmon from each of four cohorts in 1999 (top), and the mean daily flows and water temperatures observed in Lower Granite Reservoir when flow was augmented (with) compared to those that may have occurred if flows had not been augmented (without; bottom).

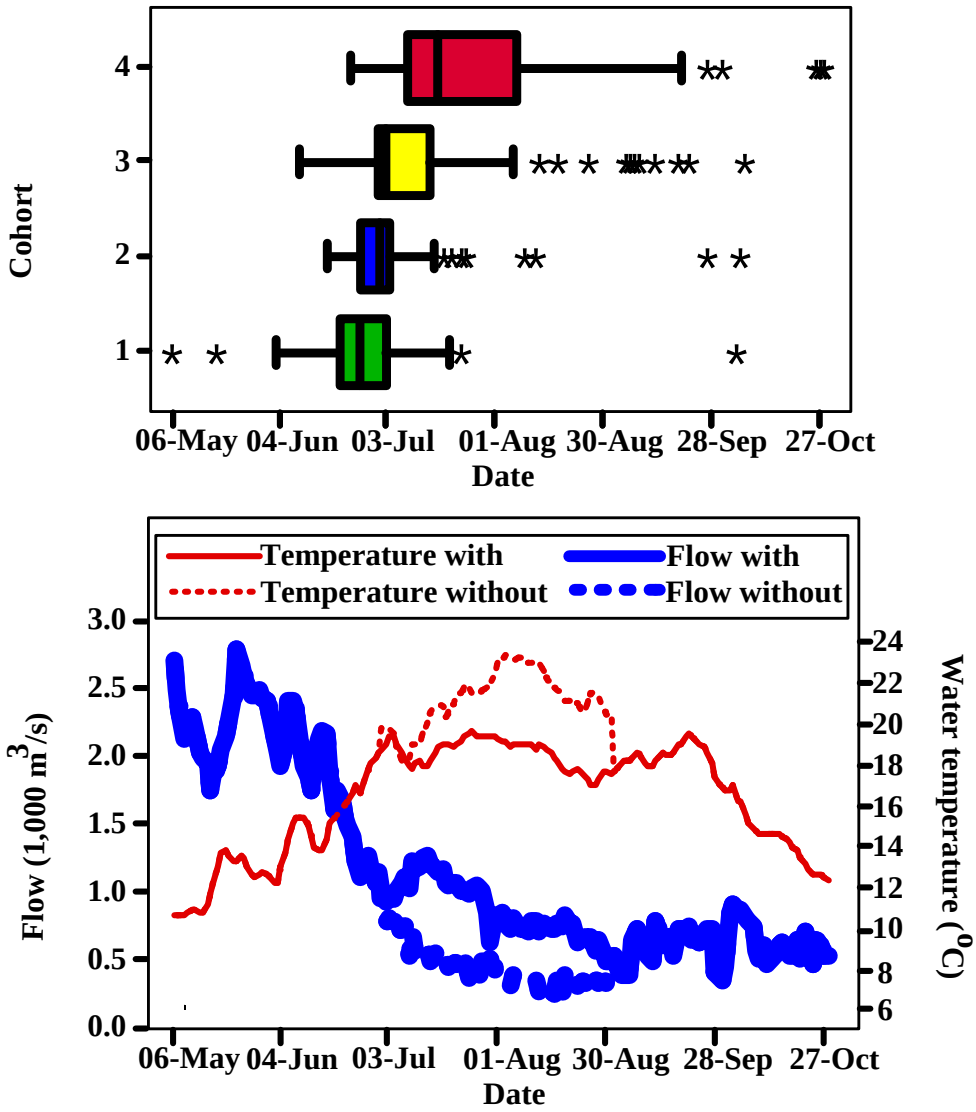

Figure 19. Box plots showing passage timing at Lower Granite Dam for PIT-tagged wild subyearling fall chinook salmon from each of four cohorts in 2000 (top), and the mean daily flows and water temperatures observed in Lower Granite Reservoir when flow was augmented (with) compared to those that may have occurred if flows had not been augmented (without; bottom).

Table 21. Predicted survival (%±95% C.I.) to the tailrace of Lower Granite Dam for cohorts of wild subyearling fall chinook salmon tagged in the Snake River from 1995 to 1998. Predictions were made using the observed flow and water temperature indices in Table 1 (Survival with), and by using flow (m^3/s) and water temperature (^oC) exposure indices recalculated to approximate conditions that would have occurred if flow had not been augmented (Survival without).

Cohort	Survival with	Recalculated		Survival without	Difference in survival
		Flow	Temperature		
			1998		
1	77.2±6.5	2,066	18.3	64.8±5.8	12.4
2	60.7±6.6	1,689	19.3	47.7±7.0	13.0
3	55.3±6.8	1,468	20.1	36.1±9.3	19.2
4	33.8±8.0	988	21.3	14.8±13.1	19.0
			1999		
1	87.3±7.5	2,128	17.1	75.0±5.2	12.3
2	70.6±4.7	1,667	18.4	53.5±4.3	17.1
3	77.5±5.8	1,837	18.0	60.9±4.0	16.6
4	45.9±4.6	943	20.1	22.2±9.4	23.7
			2000		
1	61.5±6.7	1,314	17.0	54.2±6.8	7.3
2	49.4±5.5	1,078	17.9	41.5±6.5	7.9
3	47.4±5.3	978	18.6	33.8±6.7	13.6
4	31.4±7.5	587	20.1	12.8±10.6	18.6

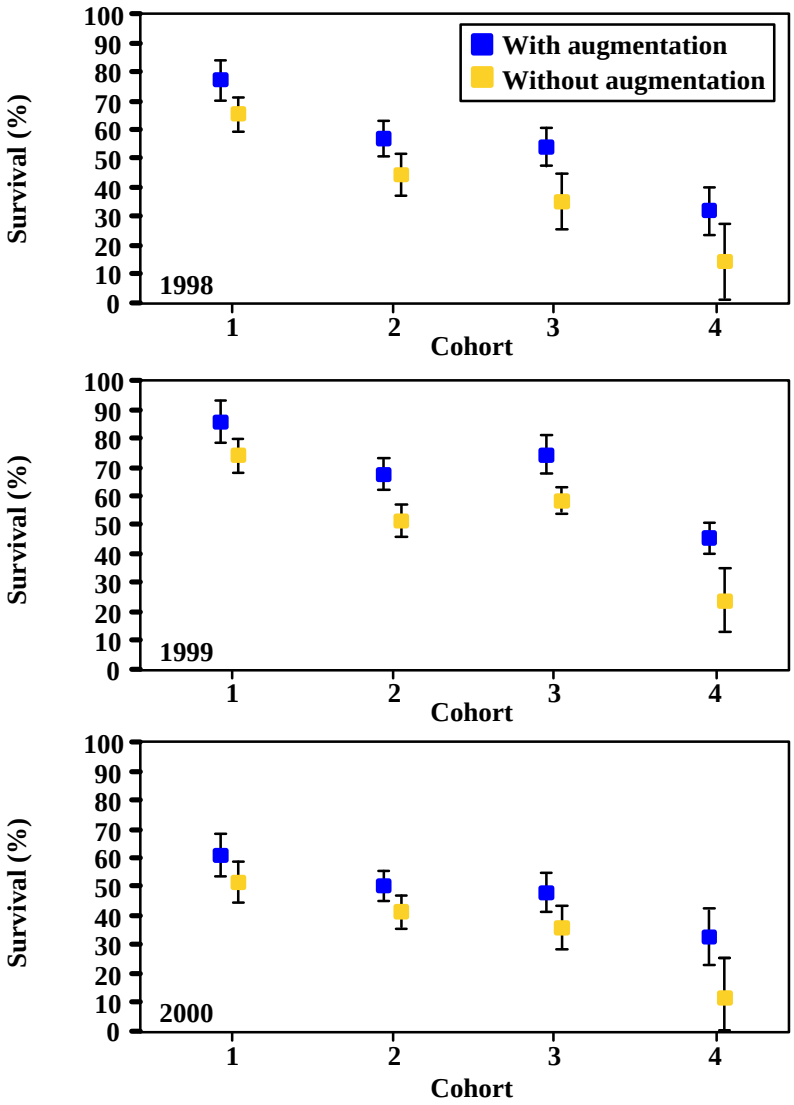

Figure 20. Survival (±95% C.I.) to the tailrace of Lower Granite Dam for PIT-tagged wild subyearling fall chinook salmon (1998 top; 1999 middle; 2000 bottom) predicted from observed mean flow and water temperatures (from Table 1), and from mean flows and water temperatures recalculated to represent those that would have occurred if flow were not augmented (from Table 3). The equation Cohort survival = 140.82753 + 0.02648 Flow -7.14437 Temperature was used to make both sets of predictions.

Fall Chinook Survival and Passage Discussion and Conclusions

Survival of wild subyearling fall chinook salmon from release in the Snake River to the tailrace of Lower Granite Dam generally increased as flow increased and decreased as temperature increased. Based on the regression model developed by Connor et al. (In press b) and reported herein, survival is predicted to change by approximately 3% with each change of 100 m^3/s in flow when temperature is held constant. The change in survival is approximately 7% for each 1^oC increase or decrease in temperature when flow is held constant. Kjelson et al. (1982), Kjelson and Brandes (1989), and Connor et al. (1998) also reported that survival of subyearling chinook salmon during seaward migration is directly proportional to flow and inversely proportional to temperature.

Flow and temperature were closely correlated in the above three studies (e.g., r = -0.999; Connor et al. 1998), thus the researchers could not determine if the high correlation between survival and one variable was caused by the other variable. Flows and temperatures were atypically uncorrelated (r = -0.45) fin the 1998-2000 Connor et al. (In press b) study, therefore the researchers were able to enter both of these predictor variables in the same multiple regression equation without detectably biasing the regression coefficients. Both regression coefficients differed significantly from zero (flow $P \leq 0.0001$; temperature $P = 0.003$). Connor et al. (In press b) conclude that flow and temperature act together to influence fall chinook salmon survival.

After a candid discussion on the shortcomings of their study, Connor et al. (In press b) concluded that summer flow augmentation increased the survival of young fall chinook salmon passing downstream in Lower Granite Reservoir especially when flow releases were timed to the passage of smolts in July and August.

Spill

Employing the use of spill for juvenile migrants has long been used as an effective management tool for improving passage survival of migrating juvenile salmon at mainstem hydroelectric projects. Routing smolts through spillways at hydroelectric projects in the Columbia and Snake rivers is generally considered to be the safest passage strategy, when compared to the passage survival through bypass systems and turbine routes. Recently, analyses conducted by Muir et al. (2001) reconfirmed the findings of numerous earlier studies by demonstrating that spillway survival of smolts exceeds that incurred through both turbines and collector/bypass systems at dams on the Snake River.

Spill is also an effective tool in decreasing the amount of delay experienced by fish in forebays and tailraces of dams where predator populations and predation rates are highest. Spill can greatly reduce delay of smolts as demonstrated at the forebay of The Dalles Dam by Snelling and Schreck (1994). Spill establishes a large flow net with increased velocity that disperses predators from the forebay and tailrace areas thus reducing the potential for predator/prey interactions (Faler et al., 1988).

Spilling water can cause high dissolved gas to concentrate by entrainment of air in the form of bubbles as it passes over the spillway and plunges to the tailrace. The air is forced into solution, causing the water to become "supersaturated" at ambient atmospheric pressure with respect to dissolved gas. Water that is supersaturated with respect to dissolved gases may cause gas bubbles to form in the bodies of fish and other aquatic animals under certain conditions that impair their ability to function, or in extreme situations may lead to death. Consequently, spill management must recognize the tradeoff between survival benefits and the detrimental effects of high total dissolved gas levels.

The "Spill and 1995 Risk Management" report was developed by the region's fishery agencies and tribes document and provided part of the biological justification for the implementation of the 1995 Biological Opinion spill program. The document reviewed all available studies and quantified the trade-off between the increase in salmon survival associated with an increase in spill passage, against the potential fish mortality that might be incurred from increased levels of total dissolved gas (TDG). The assessment concluded that the benefits of spill passage outweighed the risk up to TDG levels between 120 to 125%. The annual voluntary spill program has been implemented within these constraints since that time.

In 2000 the NMFS included Appendix E in their Biological Opinion. This appendix was meant to serve as the justification and risk assessment for the spill program included in the 2000 Biological Opinion. The appendix addresses the 120% dissolved gas ceiling and builds on the findings of the 1995 document with information collected subsequently. The NMFS also uses the SIMPAS model as a means of quantifying an amount of system survival attributable to the 120% TDG spill program. The NMFS concludes, "the risk associated with a managed spill program to the 120% total dissolved gas (TDG) level is warranted by the projected 4% to 6% increase in system survival of juvenile salmonids. Recent research and biological monitoring results support the findings of the 1995 report, which predicted that the TDG in the 120% to 125% range, coupled with vertical distribution fish passage information indicating that most fish migrate at depths providing some gas compensation, would not cause juvenile or adult salmon mortalities exceeding the expected benefits of spillway passage. NMFS finds little evidence that this expected survival improvement would be reduced by the mortality related to gas bubble trauma (GBT). NMFS also concludes that physical and biological monitoring of GBT signs can continue to be used to indicate dissolved gas exposure in adult and juvenile salmon migrants."

Evidence for Spill Survival Benefits

The multiple regression analyses conducted for survival of steelhead and chinook from Lower Granite Dam to McNary Dam all include a spill related variable in the models. This suggests the importance of spill in the determination of juvenile survival.

An analysis of smolt survival in the lower Columbia River index reach was possible based on the implementation of a limited spill program during the drought year, 2001. The McNary Dam passage distribution of PIT tagged yearling chinook was split into nine multi-day blocks with at least 10,000 PIT tagged smolts per block. The plot (Figure 21) of the estimated survival from McNary Dam tailrace to Bonneville Dam tailrace shows evidence of shifts in estimated survival for yearling chinook smolts passing McNary Dam in the May 1-10, May 11-21, and May 22 to

June 9 periods. Spill at The Dalles and Bonneville dams only began on May 16 and at John Day Dam on May 25. It is likely that the survival data is grouped due to the impacts of spill, with higher survivals estimated during periods of higher spill. Further evidence implicating spill as a causal factor in increasing survival is based on the significant change in collection efficiency at John Day Dam, dropping nearly 45% for yearling chinook post initiation of spill, suggesting a far greater proportion of fish passing over the spillway at John Day Dam.

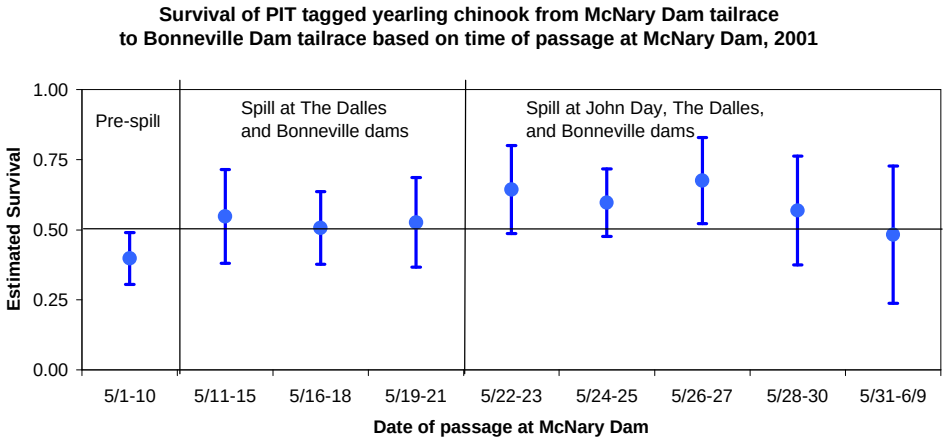

Figure 21. Survival of PIT tagged yearling chinook from McNary Dam tailrace to Bonneville Dam tailrace based on time of passage at McNary Dam, 2001.

Evidence for the Appropriateness of the Current Total Dissolved Gas Standards

The effects of elevated dissolved gas on migrating juvenile and adult salmon due to voluntary spill have been monitored each year of spill program implementation. Based on seven years of data from the biological monitoring program, the average incidence of gas bubble disease signs has been low, although the state-allowed maximum TDG due to spill was 120 percent in the tailrace and 115 percent in forebays during periods of voluntary spill. A high percentage of the spill that did occur in some years was involuntary, and often resulted in dissolved has levels above the 120% waiver. The following graphs (Figures 22 and 23) depict the incidence and severity of signs of GBT in fish collected for observation over the seven years, grouped in 5 percent TDG levels. Increases in the incidence of signs were observed with increases in the levels of TDG. The severity of signs also increased, but not until dissolved gas levels were above the 120 to 125% level.

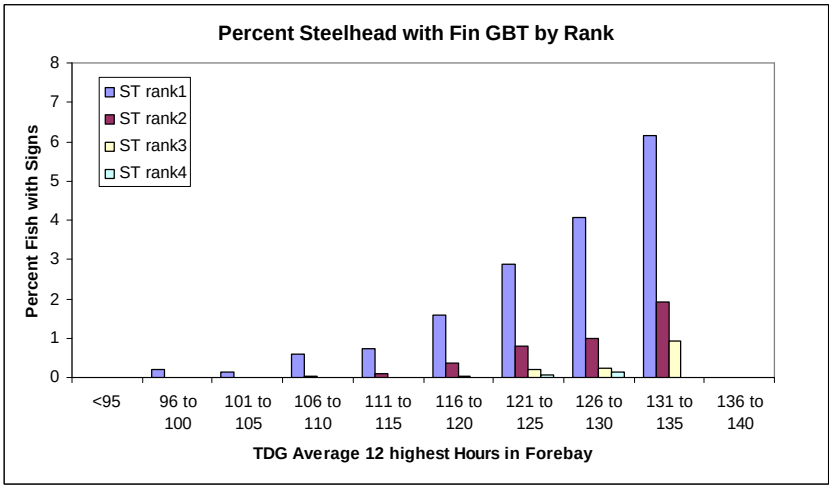

Figure 22. Percent Steelhead with Fin GBT by Rank.

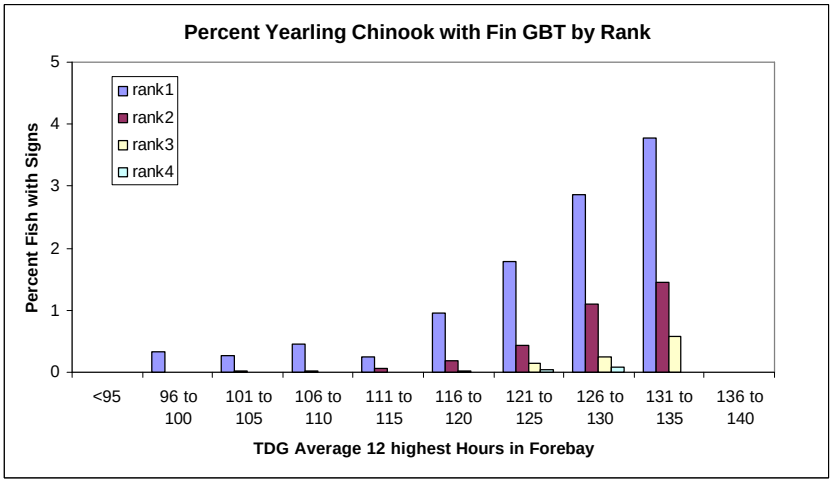

Figure 23. Percent Yearling Chinook with Fin GBT by Rank.

Additional information regarding the effects of total dissolved gas on the survival of juvenile salmonids can be ascertained from the relation between juvenile survival and total dissolved gas concentrations. The following graphs (Figures 24 and 25) depict the relation between smolt survival between the tailrace of Lower Granite to the tailrace of McNary Dam plotted as a function of the average total dissolved gas concentration at Ice Harbor indexed as described in the multiple regression analyses performed previously in this document.

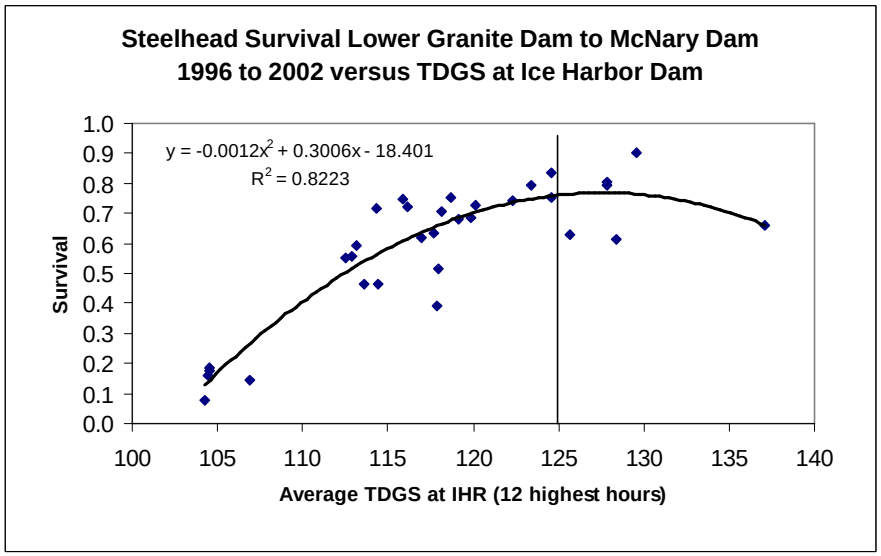

Figure 24. Steelhead Survival Lower Granite Dam to McNary Dam 1996 to 2002 versus TDGS at Ice Harbor Dam.

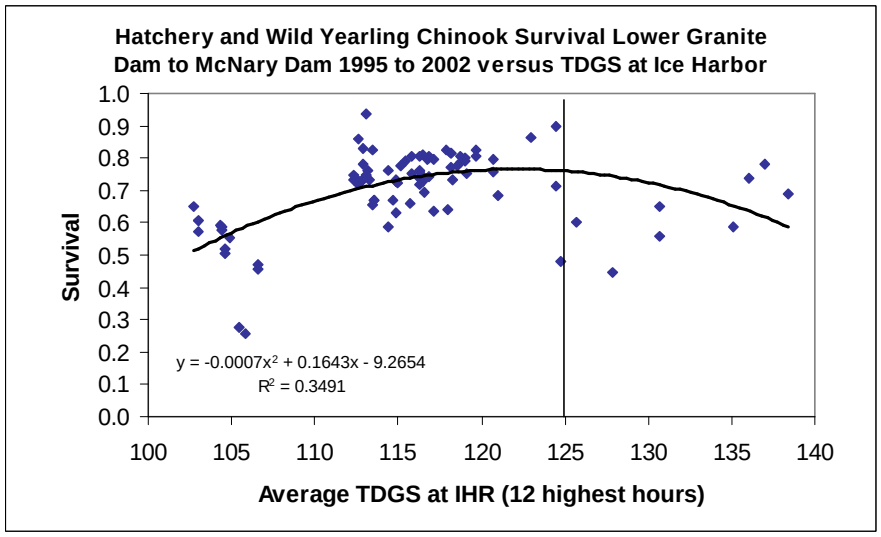

Figure 25. Hatchery and Wild Yearling Chinook Survival Lower Granite Dam to McNary Dam 1995 to 2002 versus TDGS at Ice Harbor.

These data suggest that total dissolved gas concentrations above 125% may have had a negative impact on survival. These high total dissolved gas measurements are a function of uncontrolled spill that occurred in the hydrosystem because of flow in excess of the hydraulic capacity of the project, or due to spill in excess of generation needs. They are not caused by the implementation of the Biological Opinion Spill Program.

All of the information collected to-date of survival and the benefits associated with spill indicate that spill provides a significant benefit to juvenile survival at levels up to 125% in the tailrace of the dam. The data suggest that the spill program has a built-in margin of error for total dissolved

gas. This allows the implementation of the Biological Opinion Spill Program with little or no impact due to small excursions from the 115% forebay and 120% tailrace total dissolved gas criteria.

Adult Return Analysis

We evaluated the impacts of flow and spill on the survival of smolts-to-adults and spawner-to-spawner to investigate the total impact of these factors on overall survival. The data set used in the adult analyses is presented in Table 1 (Appendix A). Because the ocean has a very large influence on these survival rates we included a measure of climate and ocean conditions in this analyses. We used the parameter delta derived in the Plan for Analyzing and Testing Hypotheses (PATH), which is a measure of climate/ocean mortality influences that are common to both spring/summer chinook stocks originating lower in the Columbia (e.g. John Day River) and in the Snake River (Deriso et al. 2001). Because these stocks are genetically very similar, have similar migration, ocean entry and adult return timing, we expect both to respond to ocean changes in a similar manner (Schaller et al. 1999, 2000). This is evidenced by the large returns occurring for all stocks during recent good ocean conditions (see Figure 26). The Yakima SARs averaged (geometric mean) nearly 4 times higher than Snake River SARs, but were similar in pattern over time to the Snake River SARs (Figure 1; Joint Technical Memorandum to NWPPC, March 19, 2002).

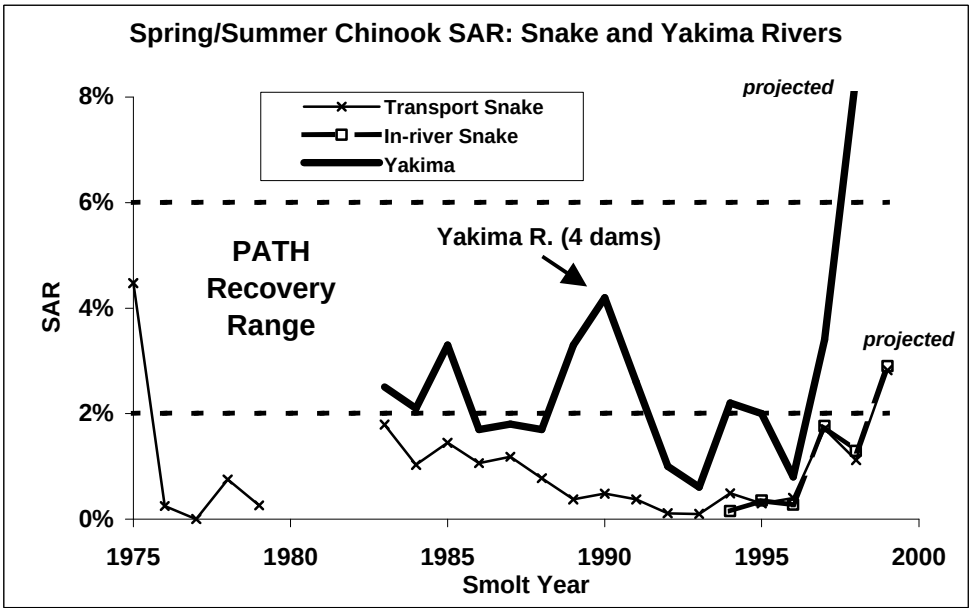

Figure 26. Smolt to adult return rates (SAR) Snake River spring/summer chinook, (transported 1975-1999; inriver migrants 1994-1999), and Yakima spring chinook, 1983-1998.

Dependent variables were wild Snake River chinook and steelhead SARs; spawner to spawner ratios from index stocks of Snake River spring/summer chinook used in PATH and NMFS Biological Opinion; and the direct and delayed hydrosystem survival of Snake River spring/summer chinook relative to downriver spring/summer chinook, estimated in PATH by the parameter mu (Deriso et al. 2001). Snake River wild chinook SARs for 1975-1994 were from

PATH and reported in NMFS (2000) white papers; SARs for 1995-1999 from the CSS annual report (Bouwes et al. 2002). Snake River steelhead SARs for 1975-1994 were from PATH and reported in NMFS (2000) white papers. The chinook spawner to spawner ratios (S:S) used in the analysis were from updated run reconstructions, as of March 2002. The S:S ratio used in this analysis was the median of the seven index stocks. Independent variables included water travel time, two measures of spill , updated estimates of climate effects (delta), and the proportion of smolts that were transported in barges and trucks. Annual water travel times (WTT) were the average times for water to move through the hydrosystem, LGR reservoir to BON dam, between April 16-May 31 and estimated as function of reservoir volume and flow. The proportion of water spilled each migration year (PropSpill) was represented as the daily spill/flow averaged over the migration season and across the 8 projects. Average volume spilled was calculated as daily spill averaged over the migration season and across all projects. The transport proportion was calculated as the number of smolts arriving at LGR dam divided by the number of smolts transported at LGR, LGS, and LMN over the whole season. The number of smolts arriving at LGR dam was estimated by methods described in Petrosky et al. (2001). The data source for the number of smolts transported came from Park (1985) for migration years 1975-1980, FTOT reports for migration years 1981-1984 and from the Fish Passage Center database from 1985-1996. Calvin Peters (ESSA Technologies, personal communication, March 2002) provided updated estimates of the climate effect (delta) and relative hydrosystem survival of Snake River versus downriver stocks (mu) (Deriso et al. 2001), through the 1995 migration year.

We transformed the dependent (SAR and S:S) variables by natural logarithms. We regressed Snake River spring/summer chinook ln(SARs) between 1975 (the year the last dam went in on the Snake River) and 1996 (SARs were not available between migration years 1985-1991) to all possible combinations of the above water travel time ,spill, climate, and transportation proportion variables. In addition, we conducted a stepwise regression between these response and explanatory variables to avoid using explanatory variables that were highly correlated with each other.

Both BIC scores and the stepwise regression suggested that the most parsimonious model (the model with the fewest number of explanatory variables explaining the greatest amount of variability in survival) that best explained spring/summer chinook SARs was the transportation proportion (Appendix A, Tables 2 and 3). We found a moderate to strong relationship between chinook SARs and transportation proportion (r^2=0.64, $p<0.001$); however this relationship was negative suggesting years in which the proportion transported increased the SARs decreased (Figure 27).

After demonstrating the large negative influence of transportation proportion on spring/summer chinook SARs (the best 10 models all included this variable), we evaluated the influence of other variables on survival of transported and non-transported fish over these life-stages by removing this variable from the model. BIC scores and the stepwise regression suggested that spring/summer chinook SARs were best explained by WTT and climate effects (Appendix A, Tables 4 and 5). A moderate relationship was observed between SARs explained by WTT and climate effects (r^2=0.48, $p<0.03$).

We also did a similar regression analyses for spring/summer chinook spawner-to-spawner ratios ln(S:S) because we had a more complete time series and data were collected in a similar fashion over the time series. The spawner/spawner ratio for chinook was best explained by WTT and climate effects (r^2=0.63, p<0.001; Appendix A, Tables 6 and 7).
Regression analyses were also performed on the relative hydrosystem mortality (mu) using the explanatory variables. The best model explaining relative hydrosystem mortality was WTT (r^2=0.42, p<0.002, Appendix A Tables 8 and 9). As WTT increased the relative hydrosystem mortality also increased (Figure28).

Finally, using the same regression analyses we evaluated the variables that influenced steelhead SARs. The best model selected suggested a moderate relationship between steelhead SARs and water travel time, the interaction between spill and water travel time, and climate (r^2=0.52, p<0.007).

Although these relationships are not driven by water travel time in itself, given the numerous environmental factors that influence survival of salmonids over this large portion of their life cycle as well as the large variability in the data, this factor remained as an important contributor to salmon survival.

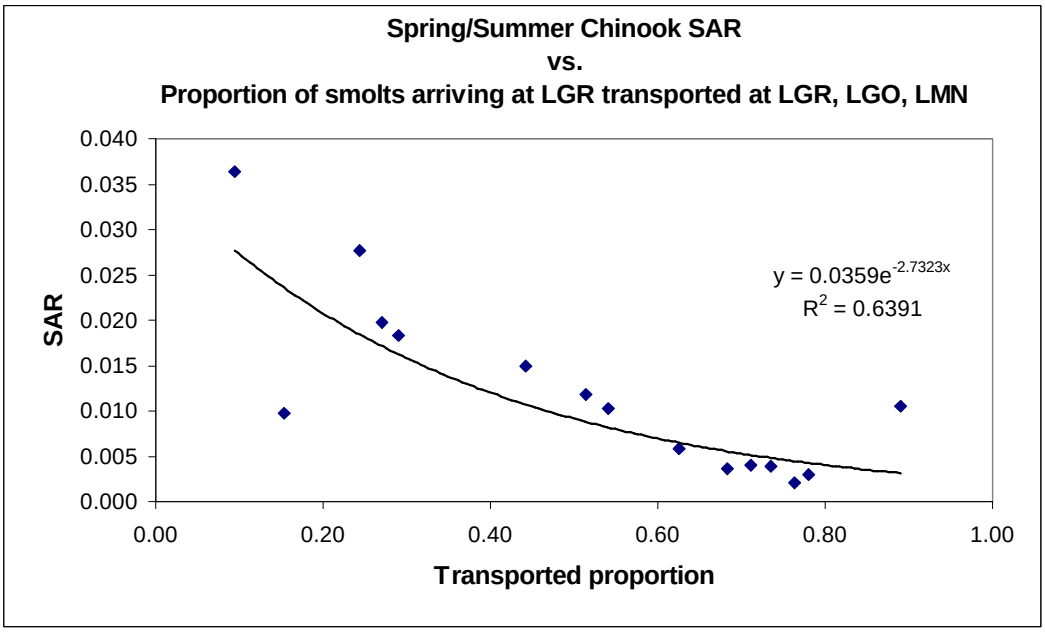

Figure 27. Relationship between Snake River spring/summer chinook smolt-to-adult survival (SAR) and the proportion of smolts arriving LGR that were transported at LGR, LGO, LMN.

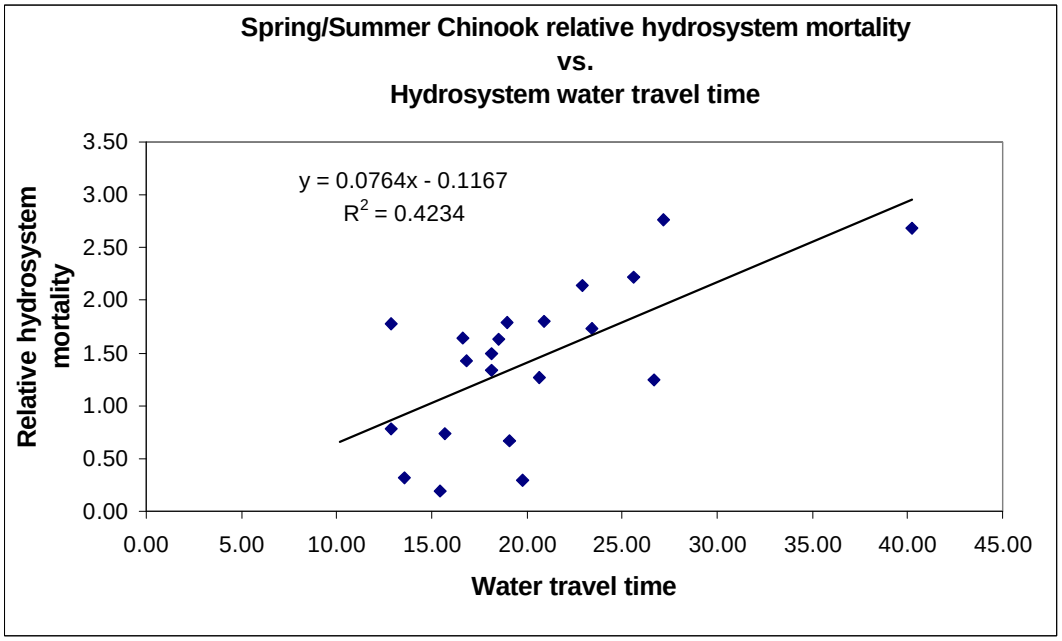

Figure 28. The relationship between water travel time through the hydrosystem and the hydrosystem mortality for Snake River spring/summer chinook relative to Lower-Columbia River spring/summer chinook (mu). Relationships of Spawner:Spawner Ratios to Water Travel Time and Climate/Ocean Conditions.

Juvenile migration conditions and climate/ocean conditions were both influential in explaining patterns of adult recruitment of wild Snake River spring/summer chinook. The relationship of predicted spawner-to-spawner ratios to water travel time and the climate/ocean influence (delta) is shown in Table 22 and Figure 29. The water travel times from Biological Opinion spring flow targets range from approximately 16.5 to 20 days, and are shaded in Table 22 and Figure 29. Observed water travel times ranged from 14 to 46 days in the fitted data (11 days was observed in 1997); and delta ranged from –1.9 (poor ocean) to 1.0 (favorable ocean). Salmon managers have no control of climatic/ocean conditions, thus we focus this discussion on predicted life-cycle survival (S:S ratio) at different water travel times, for average (delta = 0), good (delta = 1.0) and poor (delta = -1.0) climate/ocean conditions. A delta value of 1.0 indicates climate/ocean influence resulted in nearly a three-fold higher than average survival (exp(1.0)); a delta value of –1.0 indicates ocean survival was only about 1/3 as high as average. The time frame in designating “average”, “poor” or “good” climate/ocean conditions was 1959-1995 smolt migration years (Deriso et al. 2001).

Table 22. Predicted spawner:spawner ratios from observed ln(S:S), water travel time (WTT) and climate/ocean influence (delta), Snake River spring/summer chinook, smolt migration years 1975-1995. Combinations of WTT and delta that predict population declines (S:S < 1.0) are in red, those that predict population increases (S:S > 1.0) are bolded. BiOp flow targets produce WTT in the range of 16.5 to 20 days (shaded cells). Good, average, and poor climate/ocean conditions are represented by delta = 1.0, 0, and –1.0 respectively.

	DELTA								
WTT	**-1**	**-0.75**	**-0.5**	**-0.25**	**0**	**0.25**	**0.5**	**0.75**	**1**
10	0.57	0.73	0.93	**1.18**	**1.50**	**1.90**	**2.42**	**3.07**	**3.90**
15	0.40	0.51	0.65	0.82	**1.05**	**1.33**	**1.69**	**2.15**	**2.73**
20	0.28	0.36	0.45	0.58	0.73	0.93	**1.18**	**1.50**	**1.91**
25	0.20	0.25	0.32	0.40	0.51	0.65	0.83	**1.05**	**1.34**
30	0.14	0.17	0.22	0.28	0.36	0.46	0.58	0.74	0.93
35	0.10	0.12	0.16	0.20	0.25	0.32	0.40	0.51	0.65
40	0.07	0.09	0.11	0.14	0.18	0.22	0.28	0.36	0.46
45	0.05	0.06	0.08	0.10	0.12	0.16	0.20	0.25	0.32

Under average climatic/ocean conditions (delta = 0), the predicted spawner-to-spawner ratio exceeded 1.0 (indicating population growth) only when water travel times were faster than 16 days (Table 22; Fig. 29). Predicted spawner to spawner ratios for water travel times associated with the Biological Opinion flow targets would approach or meet replacement of the populations for average climatic/ocean conditions. At 30 days WTT, the predicted recruits to the spawning ground were only 36% of the parent generation. At 20 days WTT, 73% of the parent generation was predicted to return to the spawning grounds, over a doubling of life cycle survival for a 10 day reduction in WTT, but insufficient for the population to increase.

Under good climatic/ocean conditions (delta = 1.0), the predicted spawner-to-spawner ratio exceeded 1.0 (indicating population growth) when water travel times were faster than 29 days (Table 22; Fig. 29). Predicted spawner to spawner ratios for water travel times associated with the Biological Opinion flow targets would exceed replacement of the populations for good climatic/ocean conditions. At 30 days WTT, the predicted recruits to the spawning ground were 93% of the parent generation. At 20 days WTT, 191% of the parent generation was predicted, again over a doubling of life cycle survival for a 10-day reduction in WTT.

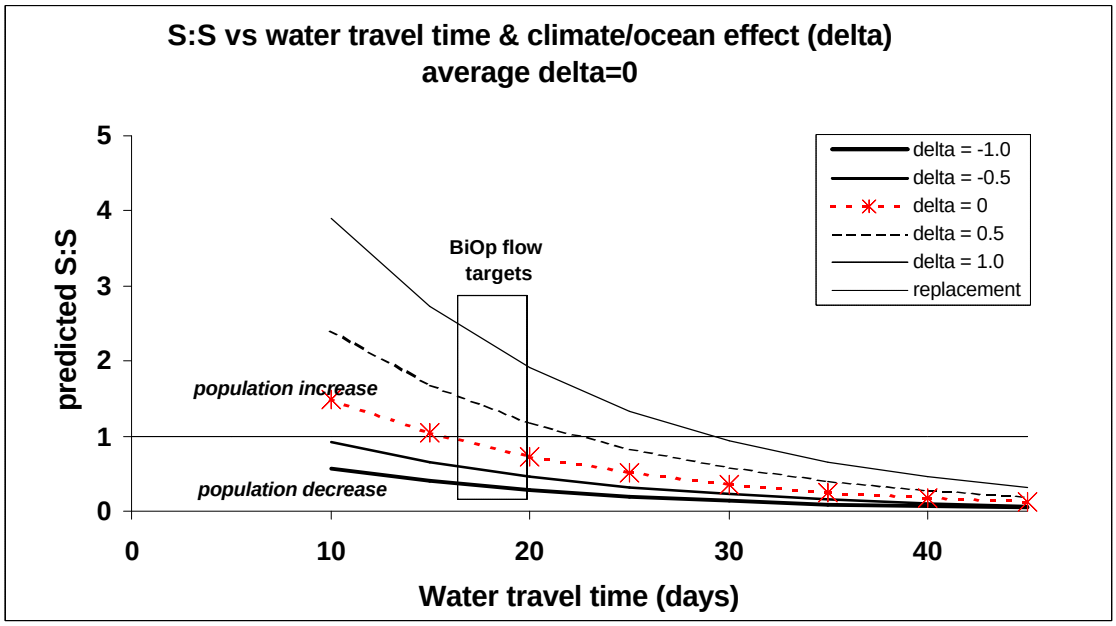

Figure 29. Predicted spawner:spawner ratios from observed ln(S:S), water travel time (WTT) and climate/ocean influence (delta), Snake River spring/summer chinook, smolt migration years 1975-1995. Population increases when S:S exceeds 1.0; and decreases when S:S < 1.0. BiOp flow targets produce WTT in the range of 16.5 to 20 days.

Under poor climatic/ocean conditions (delta = -1.0), the predicted spawner-to-spawner ratio was always less than 1.0 (indicating population decline) at all water travel times (Table 22; Fig. 29). Predicted spawner-to-spawner ratios for water travel times associated with the Biological Opinion flow targets would provide protection for the populations for poor climatic/ocean conditions, but be insufficient to prevent declines. At 30 days WTT, the predicted recruits to the spawning ground were only 14% of the parent generation. At 20 days WTT, 28% of the parent generation was predicted to return to the spawning grounds.

It is important to recognize that the relationships described above are inherently optimistic because we fit a density independent model. In reality, as the population increased toward carrying capacity, egg-to-smolt survival would decrease, and higher SARs would be needed for population growth to occur. For a given ocean condition, faster water travel times would be needed to maintain or rebuild the populations at higher spawner levels, particularly if regional harvest goals were to be achieved.

The Biological Opinion flow targets appear to represent a minimum needed to maintain the Snake River spring/summer chinook populations for average to good ocean conditions, and provide inadequate protection for poor ocean conditions. The Council's proposed relaxation of spring flow targets would increase water travel times and reduce protection against population declines and the likelihood of rebuilding Snake River spring/summer chinook.

Relationships of Chinook and Steelhead SARs to Water Travel Time and Climate/Ocean Conditions

Juvenile migration conditions and climate/ocean condition were both influential in explaining patterns of smolt-to-adult survival rates (SARs) of wild Snake River spring/summer chinook and steelhead. The relationships of predicted chinook and steelhead SARs to water travel time and the climate/ocean influence (delta) are shown in Figures 30 and 31. The water travel times from Biological Opinion spring flow targets range from 16.5 to 20 days, and are shaded in the figures. Observed water travel times ranged from 14 to 46 days in the fitted data; and delta ranged from –1.9 (poor ocean) to 1.0 (favorable ocean). We again focus this discussion on predicted smolt-to-adult survival at different water travel times, for average (delta = 0), good (delta = 1.0) and poor (delta = -1.0) climate/ocean conditions.

PATH estimated a median 4% SAR was needed for spring/summer chinook recovery, and 2% SAR to meet survival criteria. PATH did not establish a steelhead SAR range associated with survival and recovery criteria.

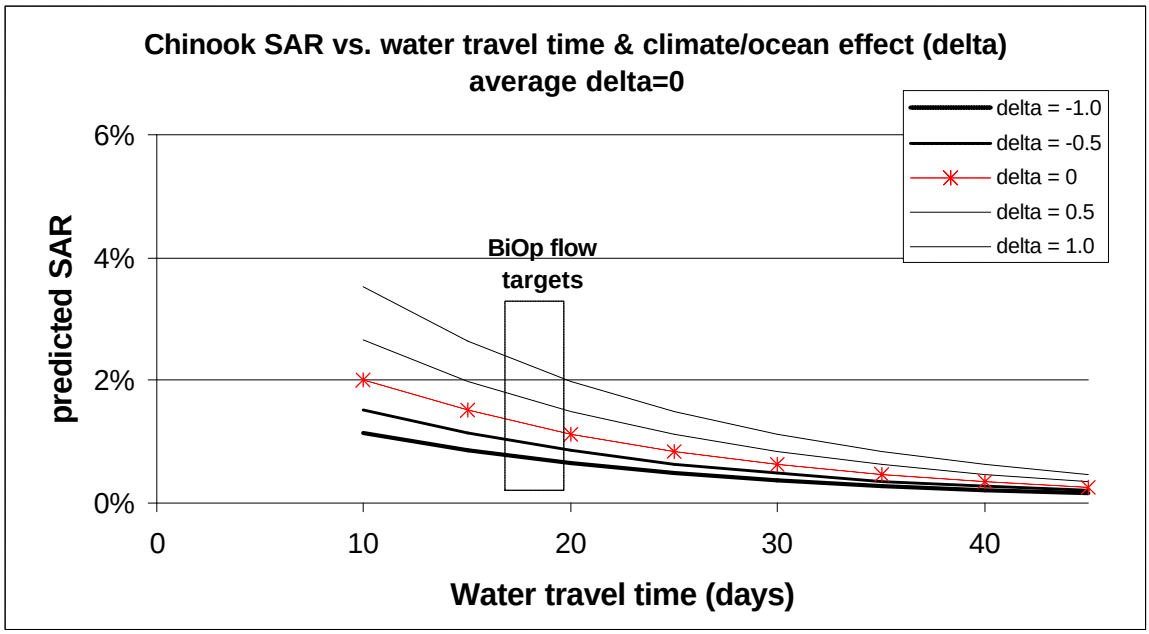

Figure 30. Predicted SAR from observed ln(SAR), water travel time (WTT) and climate/ocean influence (delta), Snake River wild spring/summer chinook, smolt migration years 1975-1995. Estimated SAR range needed for recovery is 2%-6%. BiOp flow targets produce WTT in the range of 16.5 to 20days.

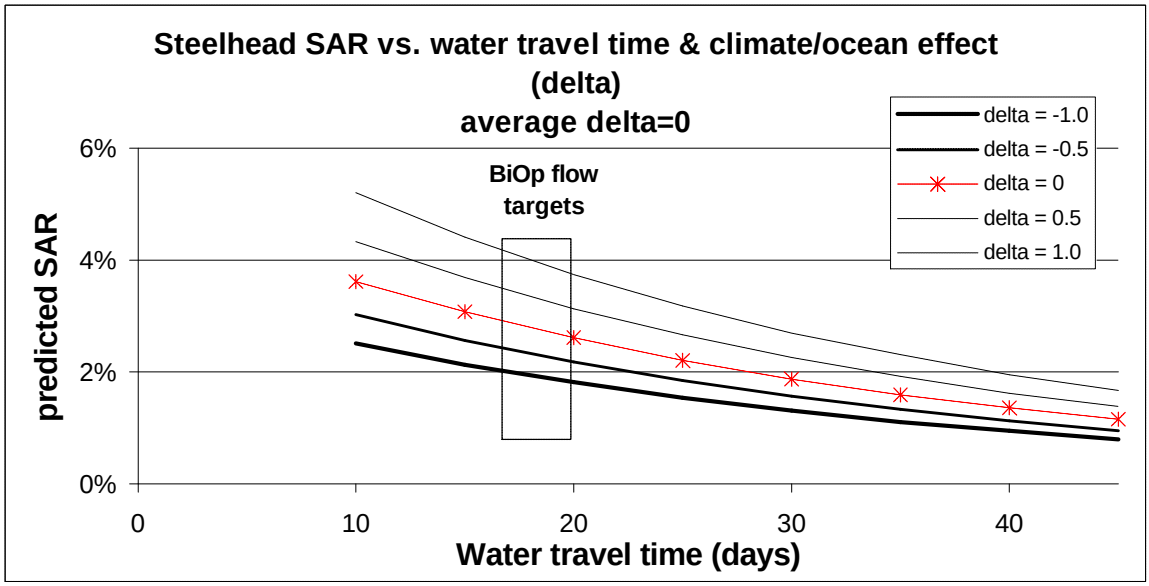

Figure 31. Predicted SAR from observed ln(SAR), water travel time (WTT) and climate/ocean influence (delta), Snake River wild steelhead, smolt migration years 1975-1995. SAR range needed for recovery has not been established. BiOp flow targets produce WTT in the range of 16.5 to 20days.

Under average climate/ocean conditions (delta = 0), the predicted SARs for spring/summer chinook exceeded 2% only at the high flows and water velocities (WTT = 10 days; Fig. 30). Predicted SARs for water travel times associated with the Biological Opinion flow targets ranged from 1.1% to 1.4% for average climatic/ocean conditions. At 30 days WTT, the predicted SARs were only 0.6%. At 20 days WTT, predicted SARs were 1.1%, a 78% improvement in life stage survival for a 10-day reduction in WTT, but less than the SAR range identified in PATH as needed for survival and recovery.

Under average climate/ocean conditions, the predicted steelhead SARs for water travel times associated with the Biological Opinion flow targets ranged from 2.6% to 2.9% (Fig. 31). At 30 days WTT, the predicted SARs were 1.9%. At 20 days WTT, predicted SARs were 2.6%, a 39% improvement in life stage survival for a 10-day reduction in WTT.

Under favorable climate/ocean conditions (delta = 1.0), the predicted SARs for spring/summer chinook exceeded 2% at average and above flows and faster water velocities (WTT = 20 days; Fig. 30). Predicted SARs for water travel times associated with the Biological Opinion flow targets ranged from 2.0% to 2.4% for good climatic/ocean conditions. At 30 days WTT, the predicted SARs were only 1.1%. At 20 days WTT, predicted SARs were 2.0%, a 78% improvement in life stage survival for a 10-day reduction in WTT, and within the SAR range identified by PATH as needed for survival and recovery.

Under good climate/ocean conditions, the predicted steelhead SARs for water travel times associated with the Biological Opinion flow targets ranged from 3.75% to 4.2% (Fig. 31). At 30

days WTT, the predicted SARs were 2.7%. At 20 days WTT, predicted SARs were 3.75%, a 39% improvement in life stage survival for a 10-day reduction in WTT.

Under poor climate/ocean conditions (delta = -1.0), the predicted SARs for spring/summer chinook never approached 2% at any flows and water velocities (Fig. 30). Predicted SARs for water travel times associated with the Biological Opinion flow targets ranged from 0.65% to 0.8% for poor climatic/ocean conditions. At 30 days WTT, the predicted SARs were only 0.36%. At 20 days WTT, predicted SARs were 0.65%, a 78% improvement in life stage survival for a 10 day reduction in WTT, but much lower than the SAR range identified by PATH as needed for survival and recovery.

Under poor climate/ocean conditions, the predicted steelhead SARs for water travel times associated with the Biological Opinion flow targets ranged from 1.8% to 2.0% (Fig. 31). At 30 days WTT, the predicted SARs were 1.3%. At 20 days WTT, predicted SARs were 1.8%, a 39% improvement in life stage survival for a 10-day reduction in WTT.

Results from this study suggest that relaxation of spring flow objectives from those specified in the Biological Opinion would likely decrease the SARs of wild Snake River spring/summer chinook and steelhead.

TRANSPORTATION

Several studies summarized in Giorgi et al. (2002) provide mechanisms and empirical information that suggests that increasing flow decreases the amount of time a smolt spends in the hydrosystem and subsequently mortality. Giorgi et al. (2002) also summarizes results reported by NMFS, which have not been able to reject hypotheses that increases in flows have no benefit to salmon survival. Based on this study, the Council has suggested relying mainly on transportation as mitigation for the impacts of the hydropower system rather than meeting flow targets. However, the benefits to transportation also remain equivocal. The Giorgi et al. (2002) report reviewed Bouwes et al. (2001) and Sandford and Smith (2002) as recent studies evaluating the benefit of transportation relative to migrating through the hydrosystem. Giorgi et al. (2002) concluded that transported fish generally exhibited higher SARs than fish that migrate in-river. Giorgi et al. (2002) failed to emphasize the important conclusions to these studies relevant to actual hydrosystem operations. Emphasis should have been placed on the comparison between wild smolts transported at all sites to the control, wild smolts that experienced a migration through the hydrosystem as if the transportation/collection system were not in place. Bouwes et al. (2001) found in 4 out of the 6 years analyzed, transported wild fish actually exhibited slightly lower SARs (point estimates) than wild fish that migrated through the hydrosystem undetected. Sandford and Smith (2002) also demonstrated equivocal differences between transported (they did not evaluated total transport SAR from all projects) and control in-river migrants as only 4 out 20 data sets demonstrated significant benefits to an optimistic representation of transportation. See Joint Technical Memorandum to NWPPC, March 19, 2002.

Our analysis also does not support the hypothesis that transportation provides a benefit to the overall survival of wild spring/summer chinook and steelhead. The spring/summer chinook S:S and steelhead SARs were not significantly influenced by the transportation proportion, and the spring/summer chinook SARs actually decreased as the proportion of smolts transported

increased. Because transportation has failed to demonstrate statistically significant increases over fish that migrate in-river, by applying similar logic used to reject flow target as a management tool, we would expect the Council to adopt a management action that ceased transportation as well. The Council's draft mainstem amendments to the Fish and Wildlife program appear to apply a double standard to what are acceptable and unacceptable management strategies.

Because the benefits of flow and transportation are not clear the region has adopted a spread the risk approach whereby both flow augmentation and transportation strategies be used as partial mitigation to the hydrosystem. The Council has proposed a spread the risk approach only for transportation, however; based on our results removing flow targets will increase the risk to populations evaluated in this analysis.

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APPENDIX A

Table 1: Information used in analysis. See text for details on data compilation of SARch (Snake River spring/summer chinook smolt-to-adult survival), lnSSch (Snake River spring/summer chinook ln Spawner to Spawner), mu (direct and delayed hydrosystem survival of Snake River spring/summer chinook relative to Mid-Columbia spring/summer chinook survival), SARst (Snake River steelhead smolt-to-adult survival), wtt (water particle travel time through Lower Granite Reservoir to Bonneville Dam), spill (average proportion of the flow spilled over dams), avgspill (average volume-kcfs-spilled over dams), climate (climate affect), ptranss (proportion of Snake River spring/summer chinook smolts arriving at LGR, LGO, LMN that were transported in barges and trucks), ptranst(proportion of Snake River steelhead smolts arriving at LGR, LGO, LMN that were transported in barges and trucks)

Obs	year	SARch	lnSSch	mu	SARst	wtt	spill	avgspill	climate	ptranss	ptranst
1	1975	0.036	-0.347	0.74	0.021	15.71	0.406	69.74	0.22	0.09	0.17
2	1976	0.010	-0.905	1.78	0.020	12.89	0.481	112.36	-0.18	0.15	0.14
3	1977	0.004	-2.031	2.68	0.010	40.23	0.004	0.82	-0.41	0.68	0.64
4	1978	0.010	-0.641	1.33	0.033	18.16	0.145	29.28	-0.50	0.54	0.65
5	1979	0.012	-0.410	0.29	0.034	19.75	0.073	16.46	-1.26	0.51	0.66
6	1980	0.006	-1.405	1.49	0.027	18.11	0.081	19.34	-0.45	0.63	0.79
7	1981	0.015	-0.153	1.27	0.012	20.65	0.089	20.72	-0.33	0.44	0.74
8	1982	0.018	1.281	0.32	0.040	13.55	0.355	85.41	0.15	0.29	0.53
9	1983	0.020	0.504	0.19	0.034	15.45	0.326	74.31	-0.33	0.27	0.67
10	1984	0.028	0.489	0.78	0.046	12.84	0.300	74.92	0.22	0.24	0.65
11	1985	.	1.556	0.67	0.040	19.06	0.109	22.36	0.87	0.69	1.00
12	1986	.	-0.240	1.64	0.041	16.64	0.210	48.27	0.33	0.64	0.92
13	1987	.	-0.786	2.22	0.052	25.58	0.053	11.73	0.42	0.64	0.96
14	1988	.	-0.425	1.25	0.027	26.67	0.031	5.17	-0.03	0.58	0.87
15	1989	.	-1.116	1.79	0.012	18.93	0.117	22.71	-0.49	0.60	0.80
16	1990	.	-0.444	2.14	0.030	22.92	0.108	19.45	0.58	0.64	0.85
17	1991	.	-0.570	1.81	0.019	20.91	0.161	38.75	-0.35	0.81	0.93
18	1992	0.002	-2.318	2.77	0.013	27.18	0.150	22.28	-1.09	0.76	0.93
19	1993	0.004	-2.199	1.43	0.013	16.80	0.231	56.65	-1.94	0.74	0.85
20	1994	0.010	-0.269	1.73	0.015	23.40	0.199	28.98	0.34	0.89	0.92
21	1995	0.003	-0.379	1.63	.	18.49	0.258	51.96	0.07	0.78	0.86
22	1996	0.004	-0.608	.	.	13.38	0.395	107.41	.	0.71	0.82

Table 2: Model comparisons with parameter estimates for ln (spring/summer chinook SARs) as function of wtt, spill, inter (interaction of wtt and spill estimated as wtt*spill), climate, and ptranss (see definitions to variables in Table 1). Shaded row is the best-fit model based on BIC score (lower scores are better fit models). Only the best 10 models with 3 or less explanatory variables are displayed.

Adjusted r^2	r^2	AIC	BIC	Parameter Estimates					
				Intercept	wtt	spill	inter	climate	ptranss
0.6363	0.6923	-15.7283	-12.7173	-3.36120	.	.	.	0.33405	-2.36221
0.6262	0.7124	-14.6778	-10.7195	-2.89070	.	-1.18510	.	0.38215	-2.74048
0.6210	0.7085	-14.4861	-10.6477	-3.14694	-0.01862	.	.	0.34198	-2.05827
0.6126	0.7020	-14.1795	-10.5319	-3.09728	.	.	-0.05143	0.37047	-2.48514
0.6064	0.6367	-15.4047	-13.4093	-3.34185	.	.	.	.	-2.66249
0.5868	0.6504	-13.9412	-11.7168	-3.14497	-0.01707	.	.	.	-2.39034
0.5842	0.6802	-13.1887	-10.1480	-2.29878	-0.03303	-1.65791	.	.	-2.72556
0.5789	0.6437	-13.6753	-11.5658	-3.07160	.	-0.67668	.	.	-2.90316
0.5722	0.6380	-13.4555	-11.4406	-3.24728	.	.	-0.01828	.	-2.71782
0.5643	0.6649	-12.5347	-9.8858	-2.83270	.	-4.47013	0.24669	.	-3.50571

Table 3: Relationship between SAR and WTT, PropSpill, and ptrans stepwise regression for sp/su chinook SARs

Dependent Variable: lnSARch

Stepwise Selection: Step 1

Variable ptranss Entered: R-Square = 0.6367 and C(p) = 4.0159

Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	6.13535	6.13535	21.03	0.0006
Error	12	3.50086	0.29174		
Corrected Total	13	9.63620			

Variable	Parameter Estimate	Standard Error	Type II SS	F Value	Pr > F
Intercept	-3.34185	0.32457	30.92697	106.01	<.0001
ptranss	-2.66249	0.58058	6.13535	21.03	0.0006

Bounds on condition number: 1, 1

All variables left in the model are significant at the 0.1500 level.

No other variable met the 0.1500 significance level for entry into the model.

Summary of Stepwise Selection								
Step	Variable Entered	Variable Removed	Number Vars In	Partial R-Square	Model R-Square	C(p)	F Value	Pr > F
1	ptranss		1	0.6367	0.6367	4.0159	21.03	0.0006

Table 4: Model comparisons with parameter estimates for ln (spring/summer chinook SARs) as function of wtt, spill, inter (interaction of wtt and spill estimated as wtt*spill), climate (see definitions to variables in Table 1). Ptrans was not included in this analysis. Shaded row is the best-fit model based on BIC score (lower scores are better fit models). Only the best 10 models with 3 or less explanatory variables are displayed.

Adjusted r^2	r^2	AIC	BIC	Parameter Estimates				
				Intercept	wtt	spill	inter	climate
0.3842	0.4789	-8.3548	-4.5910	-3.33244	-0.05754	.	.	0.55993
0.3710	0.5161	-7.3927	-2.3054	-2.53110	-0.07474	.	-0.11762	0.65058
0.3298	0.4844	-6.5046	-1.9849	-2.98382	-0.06657	-0.70309	.	0.60322
0.2816	0.4474	-5.5327	-1.6264	-4.52431	.	7.07556	-0.41603	0.49688
0.2474	0.3053	-6.3283	-4.3370	-3.38346	-0.06618	.	.	.
0.2160	0.3969	-4.3100	-1.1582	-3.73312	-0.04500	5.68111	-0.36117	.
0.2130	0.3340	-4.9207	-2.6783	-4.89273	.	1.88233	.	0.50695
0.2068	0.3288	-4.8120	-2.6167	-4.91379	.	8.10073	-0.42484	.
0.1927	0.2548	-5.3475	-3.6359	-4.41290	.	.	.	0.66837
0.1901	0.3147	-4.5199	-2.4507	-3.79631	-0.05458	0.84218	.	.

Table 5: Stepwise regression for sp/su chinook SARs w/o ptrans

Dependent Variable: lnSARch

Stepwise Selection: Step 2

Variable climate Entered: R-Square = 0.4789 and C(p) = 2.5236

Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	4.61479	2.30740	5.05	0.0277
Error	11	5.02141	0.45649		
Corrected Total	13	9.63620			

Variable	Parameter Estimate	Standard Error	Type II SS	F Value	Pr > F
Intercept	-3.33244	0.54054	17.34979	38.01	<.0001
wtt	-0.05754	0.02646	2.15917	4.73	0.0523
climate	0.55993	0.29245	1.67332	3.67	0.0819

Bounds on condition number: 1.0299, 4.1198

All variables left in the model are significant at the 0.1500 level.

No other variable met the 0.1500 significance level for entry into the model.

Summary of Stepwise Selection								
Step	Variable Entered	Variable Removed	Number Vars In	Partial R-Square	Model R-Square	C(p)	F Value	Pr > F
1	wtt		1	0.3053	0.3053	4.0304	5.27	0.0405
2	climate		2	0.1736	0.4789	2.5236	3.67	0.0819

Table 6: Model comparisons with parameter estimates for ln (spring/summer chinook spawner:spawner survival) as function of wtt, spill, inter (interaction of wtt and spill estimated as wtt*spill), climate, and ptranss (see definitions to variables in Table 1). Shaded row is the best-fit model based on BIC score (lower scores are better fit models). Only the best 10 models with 3 or less explanatory variables are displayed.

Adjusted r^2	r^2	AIC	BIC	Parameter Estimates					
				Intercept	wtt	spill	inter	climate	ptranss
0.6026	0.6622	-16.1548	-11.5179	1.95728	-0.09331	.	-0.12420	0.96941	.
0.5928	0.6335	-16.4417	-13.0381	1.11800	-0.07148	.	.	0.95809	.
0.5926	0.6537	-15.6327	-11.2172	1.87762	-0.09459	-1.56578	.	0.97455	.
0.5725	0.6366	-14.6194	-10.6302	1.16529	-0.06596	.	.	0.94862	-0.29051
0.4598	0.5139	-10.5078	-8.8338	0.36724	.	.	.	0.94382	-1.25700
0.4309	0.5163	-8.6127	-7.0065	0.17478	.	0.49460	.	0.94239	-1.07498
0.4292	0.5148	-8.5496	-6.9668	0.26871	.	.	0.01959	0.94290	-1.19218
0.4249	0.5111	-8.3906	-6.8666	-0.39686	.	5.40226	-0.29117	0.95190	.
0.4241	0.4817	-9.1622	-7.8601	-0.63634	.	1.69162	.	0.96638	.
0.4039	0.4337	-9.3035	-8.1231	-0.31694	.	.	.	0.99816	.

Table 7: Stepwise regression for ln(spawner/spawner) sp/su chinook

Dependent Variable: lnSSch

Stepwise Selection: Step 2

Variable wtt Entered: R-Square = 0.6335 and C(p) = 1.7233

Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	12.46888	6.23444	15.56	0.0001
Error	18	7.21289	0.40072		
Corrected Total	20	19.68177			

Variable	Parameter Estimate	Standard Error	Type II SS	F Value	Pr > F
Intercept	1.11800	0.48035	2.17074	5.42	0.0318
wtt	-0.07148	0.02282	3.93244	9.81	0.0058
climate	0.95809	0.21664	7.83736	19.56	0.0003

Bounds on condition number: 1.0035, 4.014

All variables left in the model are significant at the 0.1500 level.

No other variable met the 0.1500 significance level for entry into the model.

Summary of Stepwise Selection								
Step	Variable Entered	Variable Removed	Number Vars In	Partial R-Square	Model R-Square	C(p)	F Value	Pr > F
1	climate		1	0.4337	0.4337	8.8409	14.55	0.0012
2	wtt		2	0.1998	0.6335	1.7233	9.81	0.0058

Table 8: Model comparisons with parameter estimates for mu (relative hydrosystem mortality of spring/summer chinook) as function of wtt, spill, inter (interaction of wtt and spill estimated as wtt*spill), climate, and ptranss (see definitions to variables in Table 1). Shaded row is the best-fit model based on BIC score (lower scores are better fit models). Only the best 10 models with 3 or less explanatory variables are displayed.

Adjusted r^2	r^2	AIC	BIC	Parameter Estimates					
				Intercept	wtt	spill	inter	climate	ptranss
0.4828	0.5604	-23.4717	-18.6082	-1.55562	0.08454	2.46368	.	.	1.48165
0.4690	0.5487	-22.9186	-18.2906	-1.21933	0.07934	.	0.13625	.	1.10161
0.4291	0.4862	-22.1964	-19.0993	-0.27614	0.05803	.	.	.	0.96012
0.4084	0.4675	-21.4466	-18.5718	-0.88393	0.09649	.	0.11352	.	.
0.3965	0.4870	-20.2298	-16.7277	-0.67953	0.08538	-2.65864	0.27399	.	.
0.3955	0.4862	-20.1964	-16.7081	-0.27613	0.05803	.	.	0.00074325	0.96040
0.3929	0.4232	-21.7680	-19.5162	-0.11758	0.07647	.	.	.	.
0.3783	0.4405	-20.4048	-17.8369	-0.63183	0.09221	1.06168	.	.	.
0.3751	0.4689	-19.4995	-16.2959	-0.89277	0.09639	.	0.11439	-0.04097	.
0.3600	0.4240	-19.7952	-17.4054	-0.11979	0.07628	.	.	-0.03055	.

Table 9: Stepwise regression for relative mortality sp/su chinook

Dependent Variable: mu

Stepwise Selection: Step 1

Variable wtt Entered: R-Square = 0.4232 and C(p) = 2.7175

Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	4.51739	4.51739	13.94	0.0014
Error	19	6.15630	0.32402		
Corrected Total	20	10.67370			

Variable	Parameter Estimate	Standard Error	Type II SS	F Value	Pr > F
Intercept	-0.11758	0.43170	0.02403	0.07	0.7883
wtt	0.07647	0.02048	4.51739	13.94	0.0014

Bounds on condition number: 1, 1

All variables left in the model are significant at the 0.1500 level.

No other variable met the 0.1500 significance level for entry into the model.

Summary of Stepwise Selection								
Step	Variable Entered	Variable Removed	Number Vars In	Partial R-Square	Model R-Square	C(p)	F Value	Pr > F
1	wtt		1	0.4232	0.4232	2.7175	13.94	0.0014

Table 10: Model comparisons with parameter estimates for ln (steelhead SARs) as function of wtt, spill, inter (interaction of wtt and spill estimated as wtt*spill), climate, and ptranss (see definitions to variables in Table 1). Shaded row is the best-fit model based on BIC score (lower scores are better fit models). Only the best 10 models with 3 or less explanatory variables are displayed.

Adjusted r^2	r^2	AIC	BIC	Parameter Estimates					
				Intercept	wtt	spill	inter	climate	ptranst
0.4323	0.5220	-34.2612	-29.7278	-2.12802	-0.05528	.	-0.13030	0.36968	.
0.3897	0.4861	-32.8129	-28.9194	-2.22112	-0.05625	-1.60427	.	0.37760	.
0.3403	0.4444	-31.2554	-28.0354	-3.20726	-0.03910	.	.	0.35574	0.46735
0.3346	0.4046	-31.8704	-29.3959	-2.99219	-0.03272	.	.	0.36305	.
0.2101	0.2933	-28.4414	-26.9918	-2.19424	-0.05657	.	-0.12575	.	.
0.2049	0.3304	-27.5221	-25.8331	-3.50977	.	3.53358	-0.25331	0.35650	.
0.2000	0.2421	-29.0449	-27.6923	-3.65203	.	.	.	0.37972	.
0.1750	0.3053	-26.7843	-25.3817	-2.29969	-0.05065	1.46060	-0.21558	.	.
0.1694	0.3006	-26.6498	-25.2988	-2.40124	-0.05684	.	-0.10992	.	0.22259
0.1614	0.2497	-27.2451	-26.1373	-3.71540	.	0.34267	.	0.37405	.

Table 11: Stepwise regression for steelhead SARs

Dependent Variable: lnSARst

Stepwise Selection: Step 3

Variable inter Entered: R-Square = 0.5220 and C(p) = 2.8508

Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	2.63954	0.87985	5.82	0.0069
Error	16	2.41735	0.15108		
Corrected Total	19	5.05690			

Variable	Parameter Estimate	Standard Error	Type II SS	F Value	Pr > F
Intercept	-2.12802	0.52776	2.45640	16.26	0.0010
wtt	-0.05528	0.01807	1.41428	9.36	0.0075

Variable	Parameter Estimate	Standard Error	Type II SS	F Value	Pr > F
inter	-0.13030	0.06575	0.59347	3.93	0.0649
climate	0.36968	0.13361	1.15656	7.66	0.0138

Bounds on condition number: 1.6624, 12.985

All variables left in the model are significant at the 0.1500 level.

No other variable met the 0.1500 significance level for entry into the model.

Summary of Stepwise Selection								
Step	Variable Entered	Variable Removed	Number Vars In	Partial R-Square	Model R-Square	C(p)	F Value	Pr > F
1	climate		1	0.2421	0.2421	7.5439	5.75	0.0275
2	wtt		2	0.1625	0.4046	4.4967	4.64	0.0459
3	inter		3	0.1174	0.5220	2.8508	3.93	0.0649

Appendix B
Survival Estimates for Survival Analysis

Survival Estimates For Survival Analysis For Reach McNary to Bonneville ST 1999 to 2002; CH1 1999 to 2002

Species	Migr_yr	Release	Reach	Survival	Species	Migr_yr	Release	Reach	Survival
ST	1999	5/11 to 6/8	MCN to BON	0.717	CH1	1999	4/25-5/8	MCN to BON	0.672
ST	2000	5/11 to 6/8	MCN to BON	0.505	CH1	1999	5/9-5/22	MCN to BON	0.756
ST	2001	5/11 to 6/8	MCN to BON	0.217	CH1	1999	5/23-6/5	MCN to BON	0.660
ST	2002	5/11 to 6/8	MCN to BON	0.532	CH1	2000	4/25-5/8	MCN to BON	0.661
					CH1	2000	5/9-5/22	MCN to BON	0.669
					CH1	2001	4/25-5/8	MCN to BON	0.452
					CH1	2001	5/9-5/22	MCN to BON	0.516
					CH1	2001	5/23-6/5	MCN to BON	0.593
					CH1	2002	4/25-5/8	MCN to BON	0.694
					CH1	2002	5/9-5/22	MCN to BON	0.819
					CH1	2002	5/23-6/5	MCN to BON	0.671

Survival Estimates For Survival Analysis For Reach Rock Island to McNary ST 1998 to 2002; CH1 1998 to 2002

Species	Migr Yr	Release	Reach	Survival	Species	Migr Yr	Rel Dates	Reach	Survival
CH1	1998	4/21-5/4	RIS to MCN	0.589	ST	1998	4/21-5/4	RIS to MCN	0.586
CH1	1998	5/5-5/18	RIS to MCN	0.926	ST	1998	5/5-5/18	RIS to MCN	0.600
CH1	1999	4/21-5/04	RIS to MCN	0.741	ST	1998	5/19-6/1	RIS to MCN	0.455
CH1	1999	5/05-5/18	RIS to MCN	0.744	ST	1999	4/21-5/04	RIS to MCN	0.670
CH1	1999	5/19-6/01	RIS to MCN	0.794	ST	1999	5/05-5/18	RIS to MCN	0.607
CH1	2000	4/21-5/4	RIS to MCN	0.783	ST	1999	5/19-6/01	RIS to MCN	0.681
CH1	2000	5/5-5/18	RIS to MCN	0.790	ST	2000	4/21-5/4	RIS to MCN	0.913
CH1	2001	4/21-5/4	RIS to MCN	0.527	ST	2000	5/5-5/18	RIS to MCN	0.657
CH1	2001	5/5-5/18	RIS to MCN	0.677	ST	2000	5/19-6/01	RIS to MCN	0.405
CH1	2001	5/19-6/01	RIS to MCN	0.588	ST	2001	4/21-5/4	RIS to MCN	0.247
CH1	2002	4/21-5/4	RIS to MCN	0.649	ST	2001	5/5-5/18	RIS to MCN	0.230

Survival Estimates For Survival Analysis For Reach Lower Granite to McNary ST 1996 to 2002; CH1H 1995 to 2002; CH1W 1995,1996,1998 to 2002

Species	Dates	migr_yr	Reach	Survival	Species	Release	Migr_yr	Reach	Survival	Species	Release	Migr_yr	Reach	Survival
ST	4/17-4/23	1998	LGR to MCN	0.616	CH1H	4/1-4/7	1998	LGR to MCN	0.806	CH1W	4/1-4/7	1998	LGR to MCN	0.760
ST	4/24-4/30	1998	LGR to MCN	0.752	CH1H	4/8-4/14	1998	LGR to MCN	0.737	CH1W	4/8-4/14	1998	LGR to MCN	0.741
ST	5/1-5/7	1998	LGR to MCN	0.682	CH1H	4/15-4/21	1998	LGR to MCN	0.744	CH1W	4/15-4/21	1998	LGR to MCN	0.804
ST	5/8-5/14	1998	LGR to MCN	0.688	CH1H	4/22-4/28	1998	LGR to MCN	0.807	CH1W	4/22-4/28	1998	LGR to MCN	0.786
ST	5/15-5/21	1998	LGR to MCN	0.754	CH1H	4/29-5/5	1998	LGR to MCN	0.793	CH1W	4/29-5/5	1998	LGR to MCN	0.799
ST	5/22-5/28	1998	LGR to MCN	0.627	CH1H	5/6-5/12	1998	LGR to MCN	0.805	CH1W	5/6-5/12	1998	LGR to MCN	0.823
ST	4/17-4/23	1999	LGR to MCN	0.746	CH1H	5/13-5/19	1998	LGR to MCN	0.863	CH1W	5/20-5/26	1998	LGR to MCN	0.600
ST	4/24-4/30	1999	LGR to MCN	0.721	CH1H	4/1-4/7	1999	LGR to MCN	0.830	CH1W	4/1-4/7	1999	LGR to MCN	0.776
ST	5/1-5/7	1999	LGR to MCN	0.705	CH1H	4/8-4/14	1999	LGR to MCN	0.754	CH1W	4/8-4/14	1999	LGR to MCN	0.808
ST	5/8-5/14	1999	LGR to MCN	0.632	CH1H	4/15-4/21	1999	LGR to MCN	0.720	CH1W	4/15-4/21	1999	LGR to MCN	0.795
ST	5/15-5/21	1999	LGR to MCN	0.744	CH1H	4/22-4/28	1999	LGR to MCN	0.806	CH1W	4/22-4/28	1999	LGR to MCN	0.790
ST	5/22-5/28	1999	LGR to MCN	0.837	CH1H	4/29-5/5	1999	LGR to MCN	0.815	CH1W	4/29-5/5	1999	LGR to MCN	0.814
ST	4/17-4/23	2000	LGR to MCN	0.715	CH1H	5/6-5/12	1999	LGR to MCN	0.799	CH1W	5/6-5/12	1999	LGR to MCN	0.694
ST	4/24-4/30	2000	LGR to MCN	0.595	CH1H	5/13-5/19	1999	LGR to MCN	0.796	CH1W	5/13-5/19	1999	LGR to MCN	0.756
ST	5/1-5/7	2000	LGR to MCN	0.549	CH1H	5/20-5/26	1999	LGR to MCN	0.716	CH1W	5/20-5/26	1999	LGR to MCN	0.900
ST	5/8-5/14	2000	LGR to MCN	0.559	CH1H	4/15-4/21	2000	LGR to MCN	0.936	CH1W	4/8-4/14	2000	LGR to MCN	0.727
ST	4/24-4/30	2001	LGR to MCN	0.159	CH1H	4/22-4/28	2000	LGR to MCN	0.764	CH1W	4/15-4/21	2000	LGR to MCN	0.825
ST	5/1-5/7	2001	LGR to MCN	0.177	CH1H	4/29-5/5	2000	LGR to MCN	0.717	CH1W	4/22-4/28	2000	LGR to MCN	0.748
ST	5/8-5/14	2001	LGR to MCN	0.187	CH1H	5/6-5/12	2000	LGR to MCN	0.749	CH1W	4/29-5/5	2000	LGR to MCN	0.727
ST	5/15-5/21	2001	LGR to MCN	0.143	CH1H	5/20-5/26	2000	LGR to MCN	0.729	CH1W	5/6-5/12	2000	LGR to MCN	0.731
ST	5/22-5/28	2001	LGR to MCN	0.079	CH1H	4/8-4/14	2001	LGR to MCN	0.573	CH1W	5/13-5/19	2000	LGR to MCN	0.732
ST	4/24-4/30	2002	LGR to MCN	0.461	CH1H	4/15-4/21	2001	LGR to MCN	0.605	CH1W	5/20-5/26	2000	LGR to MCN	0.858
ST	5/1-5/7	2002	LGR to MCN	0.466	CH1H	4/22-4/28	2001	LGR to MCN	0.593	CH1W	4/8-4/14	2001	LGR to MCN	0.649
ST	5/8-5/14	2002	LGR to MCN	0.390	CH1H	4/29-5/5	2001	LGR to MCN	0.578	CH1W	4/15-4/21	2001	LGR to MCN	0.605
ST	5/15-5/21	2002	LGR to MCN	0.516	CH1H	5/6-5/12	2001	LGR to MCN	0.552	CH1W	4/22-4/28	2001	LGR to MCN	0.588
ST	5/22-5/28	2002	LGR to MCN	0.724	CH1H	5/13-5/19	2001	LGR to MCN	0.470	CH1W	4/29-5/5	2001	LGR to MCN	0.521
ST	4/24-4/30	1996	LGR to MCN	0.793	CH1H	5/20-5/26	2001	LGR to MCN	0.276	CH1W	5/6-5/12	2001	LGR to MCN	0.507
ST	5/1-5/7	1996	LGR to MCN	0.792	CH1H	4/22-4/28	2002	LGR to MCN	0.586	CH1W	5/13-5/19	2001	LGR to MCN	0.458
ST	5/15-5/21	1996	LGR to MCN	0.659	CH1H	4/29-5/5	2002	LGR to MCN	0.733	CH1W	5/20-5/26	2001	LGR to MCN	0.258
ST	4/17-4/23	1997	LGR to MCN	0.902	CH1H	5/6-5/12	2002	LGR to MCN	0.638	CH1W	4/22-4/28	2002	LGR to MCN	0.730
ST	4/24-4/30	1997	LGR to MCN	0.611	CH1H	5/13-5/19	2002	LGR to MCN	0.732	CH1W	4/29-5/5	2002	LGR to MCN	0.657
ST	5/1-5/7	1997	LGR to MCN	0.804	CH1H	5/20-5/26	2002	LGR to MCN	0.755	CH1W	5/6-5/12	2002	LGR to MCN	0.660
					CH1H	4/15-4/21	1995	LGR to MCN	0.725	CH1W	5/13-5/19	2002	LGR to MCN	0.640
					CH1H	4/22-4/28	1995	LGR to MCN	0.668	CH1W	5/20-5/26	2002	LGR to MCN	0.773
					CH1H	4/29-5/5	1995	LGR to MCN	0.779	CH1W	4/15-4/21	1995	LGR to MCN	0.825
					CH1H	4/15-4/21	1996	LGR to MCN	0.586	CH1W	4/22-4/28	1995	LGR to MCN	0.669
					CH1H	4/22-4/28	1996	LGR to MCN	0.683	CH1W	4/29-5/5	1995	LGR to MCN	0.795
					CH1H	4/29-5/5	1996	LGR to MCN	0.652	CH1W	5/6-5/12	1995	LGR to MCN	0.759
					CH1H	5/6-5/12	1996	LGR to MCN	0.689	CH1W	4/15-4/21	1996	LGR to MCN	0.736
					CH1H	5/13-5/19	1996	LGR to MCN	0.779	CH1W	4/22-4/28	1996	LGR to MCN	0.480
					CH1H	4/29-5/5	1997	LGR to MCN	0.444	CH1W	4/29-5/5	1996	LGR to MCN	0.556

ADULT FISHWAY INSPECTIONS
2001 ANNUAL REPORT

By

LARRY R. BASHAM

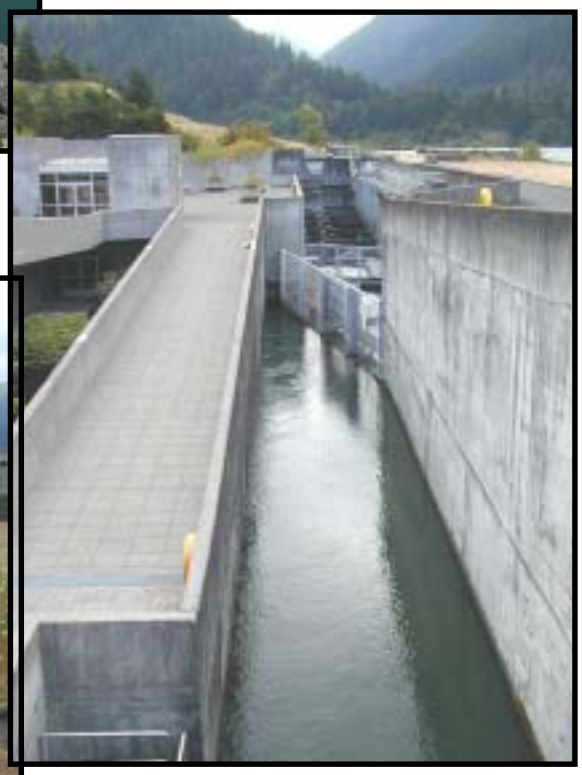
Bonneville: WA Shore Powerhouse

FISH PASSAGE CENTER

of the

COLUMBIA BASIN FISH & WILDLIFE AUTHORITY

Bonneville: WA Shore Fish Ladder Exit



WA Shore Fish Counting Station

June 2002

ADULT FISHWAY INSPECTIONS ON THE COLUMBIA AND SNAKE RIVERS

2001 ANNUAL REPORT

Larry R. Basham,
Field Operations Coordinator

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of the

COLUMBIA BASIN FISH AND WILDLIFE AUTHORITY

FINAL REPORT

JUNE 2002

Table of Contents

INTRODUCTION 1

BACKGROUND 1

GENERAL RESULTS.....3

CORPS OF ENGINEER DAMS 4
- Bonneville Dam 4
- The Dalles Dam 9
- John Day Dam.....12
- McNary Dam 15
- Ice Harbor Dam.....18
- Lower Monumental Dam.....21
- Little Goose Dam.....23
- Lower Granite Dam 26

PUBLIC UTILITY DISTRICT PROJECTS 29
- Priest Rapids Dam.....29
- Wanapum Dam 32
- Rock Island Dam.....34
- Rocky Reach Dam 37
- Wells Dam 40

SUMMARY OF RECOMMENDATIONS 43

APPENDIX A.....44

APPENDIX B (LIST OF PHOTOGRAPHS).....45
- Bonneville Dam 45
- The Dalles Dam 46
- John Day Dam.....47
- McNary Dam 48
- Ice Harbor Dam.....49
- Lower Monumental Dam.....50
- Little Goose Dam.....51
- Lower Granite Dam 52
- Priest Rapids Dam.....53
- Wanapum Dam 54
- Rock Island Dam.....55
- Rocky Reach Dam 56
- Wells Dam 57

ACKNOWLEDGMENTS 58

FISHWAY INSPECTIONS AT COLUMBIA AND SNAKE RIVER DAMS, 2001

INTRODUCTION

Fish agency personnel inspected fish passage facilities at 13 hydroelectric dams located on the Snake and Columbia rivers. These projects were inspected monthly to assure that fish facilities were being operated according to established criteria documented in the Corps of Engineer (COE) Fish Passage Plan (FPP), or in the Fishery Operating Plans for the Public Utility District (PUD) projects in the Mid-Columbia. The Fish Passage Center (FPC) continued coordination of the fishway inspection program for the State and Federal fish agencies. The FPC also coordinates special fish facility operations with fish and wildlife agencies and tribes. This report summarizes results obtained from the individual project inspections during the 2001 fish passage season.

The inspection program normally spans from April through October at most projects, with the lower dams generally completing inspections in March and November. These months encompass the main passage season for adult and juvenile fish at the mainstem dams. Fish facilities are inspected 7 or 8 times during the season by the State or Federal inspector. The FPC coordinator normally makes site visits or inspections with the inspectors at least twice during the year. The monthly project inspections were coordinated with the salmon managers as well as the operating agencies, i.e., the COE and PUD through monthly updates or forums such as the Fish Passage Operations and Maintenance Committee (FPOM). The main goal of a fishway inspection is to assess passage conditions at the time of the inspection and assure that facilities are operating according to established criteria. The agency inspector is responsible for coordinating immediate problems or out-of-criteria conditions to project personnel for resolution. The monthly update and this final report by the FPC operations coordinator will serve to alert the operating agency of problems that were noted during the inspections that will in some cases require resolution.

One significant change occurred after the September 11 bombing of the Twin Towers in New York this year. Security at the COE projects was tightened. In some cases, driving vehicles at or across dams was not allowed, and in all instances, identification and check-in procedures were required. As an example, on September 12, I was not allowed access to Little Goose Dam even though I met with the COE project biologist and was scheduled to complete inspections at Little Goose and Lower Granite dams with the ODFW biologist that day. Because of scheduling difficulties, fishways were not inspected at Ice Harbor and Lower Monumental dams in September. The PUD projects were increasing security measures at the five Mid-Columbia dams where check-in procedures and access to projects limited after the September 11 terrorist attacks.

BACKGROUND

Adult fish passage facilities were incorporated into 13 mainstem Columbia and Snake River dams as early as 1938 and into the new powerhouse at Bonneville Dam in 1981. Fish passage was blocked in the Columbia River at Grand Coulee Dam in 1938 and in the Snake River at Brownlee Dam in 1958. Fish passage criteria have been developed through the years to achieve known hydraulic conditions within a fishway that should reduce potential migration delays and mortality of upstream migrating adult fish at mainstem dams.

The COE and PUD are to operate their fish facilities within standards in the agreed upon Fish Passage Plan at COE projects or according to standards to meet the NMFS Biological Opinion at the PUD projects. The updated criteria spell out what the project should do when a major equipment failure or other problem occurs that would prevent operation of the fish facilities within best ranges. The operating agencies are responsible

for maintenance of the fish facilities and for operating them at the agreed upon criteria year round, with special or annual maintenance accomplished during the winter maintenance period. Planned fishway outages occur mainly when adult fish passage is minimal, that is during the winter season. Outages during the fish passage season require special coordination between the operating entities and the fishery agencies and tribes.

Throughout the fish passage season, project personnel daily inspect adult fish facilities. Most adult fishways operate in an automatic mode and require no manual adjustments unless the equipment malfunctions. Project operators normally restore an out-of-criteria item in the fishway back to the normal operating condition as soon as the discrepancy is found.

The State and Federal fishway inspectors usually schedule their monthly inspections with project personnel prior to the inspection; however, the inspections could be made unannounced (prior to September 11). The inspectors check into the project office or with the project biologist prior to initiating an inspection. The inspectors are responsible for contacting project operations personnel to review the inspection and coordinate problems that require correction. A completed copy of the inspection report can be left at the project or later sent to the COE project operations biologist or PUD personnel. The FPC fishway coordinator receives a copy of the inspection, reviews it, and then follows up on problem areas that were noted with the COE project or district fish biologist.

Key items recorded during an inspection include:

- *Powerhouse operations including number of fish turbines operating and at what Mw or Q, Number of spill bays operating and quantity of spill, and other measurements,*
- *Weir gate depths or width of gate opening at the main fishway entrances,*
- *Hydraulic head differentials at the entrances and along the channels,*
- *Water velocities in the collection or transportation channels,*
- *Head differentials across trashracks and picketed leads,*
- *Depth of water over the fish ladder weirs,*
- *Condition or readability of staff gages or water level sensors and related controlling equipment for the fishway elevations,*
- *A comment section to list special conditions or out-of-criteria areas.*
- *Inspections of juvenile fish facilities are normally completed while on site as well.*

The Fish Passage Center has been coordinating fishway inspections at the mainstem Columbia and Snake River projects since 1984. The 2001 season was a continuation of the long-term inspection program that the State and Federal fish agencies have endorsed since the 1960's. Funding for the inspection program comes from Idaho Department of Fish and Game (IDFG), Oregon Department of Fish and Wildlife (ODFW), Washington Department of Fish and Wildlife (WDFW), National Marine Fisheries Service (NMFS), and the United States Fish and Wildlife Service (USFWS).

GENERAL RESULTS

Inspections of fish facilities at 13 mainstem Columbia and Snake River dams were completed, where possible, on a monthly basis from March/April through October/November. Inspection reports were summarized and distributed to the Salmon Managers and COE and PUD operations biologists or operations personnel. Other pertinent adult fish passage information was disseminated weekly or bi-weekly in FPC reports.

Key factors that affected fishway operations at the mainstem dams during the 2001 fish passage season are listed below:

- This year's river flow in the Snake and Columbia rivers was the 2nd lowest on record with only 1977 having lower runoff than in 2001. Spill was minimal or non-existent during the spring and summer months in the Snake and Columbia rivers. Debris loads brought down the river due to the spring/early summer freshet were minor this season with presence of debris causing few known problems related to operating fish facilities. Water clarity was higher than normal during the fish passage season.
- The Snake River projects were again operated at Minimum Operating Pool (MOP) plus 1-ft during the spring and summer months to improve juvenile fish passage conditions. The additional 1-ft was required to assist passage of navigation barges up and downstream through the lock channel. During part of the passage season, some fishway entrances at the Snake River dams were operated at reduced weir depths due to the gates resting on sills (no additional depth can be achieved). In the Columbia River, Bonneville Dam was especially vulnerable to the low tailwater elevations with the main fishway entrances at the New and Old powerhouses on sill for 3-4 months this season.
- Mechanical failures on essential fishway equipment such as fish pumps, fish turbines, or other auxiliary water equipment were minimal during the 2001 fish passage season.
- Little Goose, Lower Monumental and The Dalles dams operated their powerhouse collection facilities without the orifice gates in service in 2001. Based on radio telemetry information, passage of adult fish at these projects was not compromised and the orifice gates will remain closed for the upcoming 2002 and future years. Priest Rapids and Wanapum dams also operated their collection channels without orifice gates open for part of the fish passage season to test passage of adult fish with orifice gates closed. In 2002, these orifice gates will be permanently closed as tests concluded that adult fish passage was acceptable without them operating along the collection channel.
- In summer and fall, large quantities of floating aquatic grasses such as milfoil, elodea, etc., were present in the upper and lower Columbia Rivers and these grasses caused problems with trashracks, diffuser gratings, and other equipment at the dams. The wall diffusers at Wells Dam (West Bank) were so loaded up with these grasses that the main entrance gate was operated at a lesser setting to reduce the head differential across the wall diffusers. Most projects were affected to some degree by the influx of these grasses at the fish facilities.
- Record numbers of spring, summer and fall-run salmon (species) passed Columbia and Snake River dams with minimal delays and/or injuries associated with passage at these projects. Conversion rates of salmon through the dams appeared satisfactory when compared to previous years.
- Water temperatures in the late summer and fall were higher than desired and may have affected fish passing through the projects during that time frame.

SUMMARY BY PROJECT

State and Federal fish agency personnel who completed fish facilities inspections throughout the fish passage season were as follows for the 2001 season.

AGENCY	INSPECTOR	DAMS INSPECTED
NMFS	Melissa Jundt	Priest Rapids & Wanapum
NMFS	Ed Meyer	Bonneville
NMFS	Larry Swenson	McNary
ODFW	Doug Case	The Dalles & John Day
ODFW	Josh Hanson	Little Goose & Lower Granite
WDFW	Steve Richards	Ice Harbor & Lower Monumental
WDFW	Stewart Mitchell	Wells
WDFW	Denise McCarver	Rock Island & Rocky Reach
WDFW	Glen Liner	Rock Island & Rocky Reach
WDFW	Steve Gacek	Rock Island & Rocky Reach

Results from inspections completed during 2001 are summarized by project below. Dates of inspections and problem areas are noted as well as special activities that occurred during the year. Criteria used to evaluate a fishway operation are found in the FPP and Operating Plan for each project.

CORPS OF ENGINEER DAMS

The four lower Columbia River dams, Bonneville to McNary, and the four Snake River dams, Ice Harbor to Lower Granite, comprise the COE projects that have adult fishways incorporated in their designs. These projects use a variety of fish turbine or pump designs and gravity-flow systems to supply water to the fishways. All COE dams have collection channels across the downstream face of the powerhouses that originally had openings (orifice or sluice gates) to provide entrance for adult fish approaching and passing along the powerhouses. In recent years, many of these collection channel gates have been closed and only the main entrance gates located at each end of the powerhouse are now operated. Another major change has been the adoption of new and "improved" spill schedules at COE projects. These spill schedules were modeled at the COE's hydraulic laboratory in Vicksburg, Mississippi and were designed to improve juvenile passage at the dams, reduce high levels of dissolved gas entrainment in the tailwater at the projects, and still provide good passage conditions for adult fish approaching the projects.

BONNEVILLE DAM (see photos page 45)

Bonneville Dam has two powerhouses: the old powerhouse (ph1) built in the late 1930s and located on the Oregon shore or south shore of the Columbia River, and the new powerhouse (ph2) completed in 1981 and located on the Washington or north shore of the Columbia River. The old powerhouse consists of ten main turbine units while the new powerhouse has eight main turbine units and two smaller fish turbines that supply auxiliary water to the WA shore fishway. Between the two powerhouses is the spillway (part of the old construction) that incorporates 18 spillbays to pass excess or designated flow past the project. The adult fishways consist of gravity-flow water provided to the auxiliary water system that supplies attraction-flow water to the main fishway entrances at ph1 and the spillway entrances. At ph2, two fish turbines supply about 5,000 cfs of water to the auxiliary water system that distributes flow to four main entrances and twelve orifice gates along the powerhouse collection channel.

Ed Meyer, NMFS, completed five inspections; Larry Basham of the FPC completed three inspections of the adult and juvenile fish facilities at Bonneville Dam during 2001. The fish facilities were inspected from late March through early November (Table 1). The normal routine followed by the inspector included:

1. The inspector contacts the project biologist(s) prior to inspecting the fishway to determine existing problem areas with the fish facilities or related equipment, and what corrective actions were being taken by the project to remedy the problems. In some cases, the project biologist accompanied the NMFS or FPC inspector;
2. Completing the on-site inspection included recording information at the powerhouse control room and from the B-Branch and Cascades Island fishway computers (when available), and comparing those readings to the on-site readings taken from staff gages or other sensors. The new powerhouse has a control panel with readings from the entrance gates, etc. that are compared to the direct site readings,
3. Normally, after the inspection, out-of-criteria problems noted by the inspector were discussed with the project biologist(s) for possible resolution; and
4. A copy of the report was sent to the project biologist and FPC after it was completed.

Powerhouse 1 Fishway

The auxiliary water supply to the fishway is gravity flow water supplied from the forebay. Normally the auxiliary water source is ample to meet fishway criteria through high and low flow tailwater elevations. The old powerhouse main entrances are operated in pairs, i.e., Gate 2 and Gate 64, or Gate 1 and Gate 65 depending on tailwater elevation. Five orifice gates or 5 sluice gates operate along the powerhouse collection channel depending on tailwater elevation, or whether research conditions dictate them being closed for the radio telemetry study.

Weir Gate 2, located at the south end of the powerhouse, had head differentials that ranged between 1.1 ft and 1.8 ft. The gate depths ranged from a low of 3.5 ft to a high reading of 9.1 ft for the season, with a reading of less than 8 ft on 5 of the 8 inspections. The criterion on gate depth was changed to include a minimum depth of 8-ft at the entrance in addition to the minimum head differential reading of 1.0 ft, with an asterisk indicating that at tailwater elevation of 13.5 ft or less, the gate depth cannot be maintained due to exceeding conduit pressure of 10 psi. The 2001 inspections showed more out-of-criteria events (shallow gate depths) than in previous years at the South Powerhouse Entrance.

Weir Gates 64/65 are located on the north end of the powerhouse with one gate operating to meet the gate depth criteria depending on the tailwater elevation. Gate 64 operated on all inspections in 2001. The gate depths at the A-Branch entrances ranged from 8.4 ft to 3.9 ft, with head differentials through the season ranging from 1.1 ft to 2.1 ft. With the extreme low flow conditions that occurred in 2001, gate depths were observed at less than 8.0 ft on 3 of 8 inspections; head differentials were operated within acceptable criteria during the 2001 fishway inspection season.

The Orifice/Sluice Gates along the powerhouse collection channel were operated intermittently during the season to test passage during the open/closed scenario using adult fish outfitted with radio tags (similar to 2000).

Channel velocities along the powerhouse collection channel ranged from 1.3 fps to 2.8 fps throughout the season. The velocity gage located at gate 62 was not working for most of the season; however, records from the south end of the channel were taken. Readings were normally within the criteria range of 1.5 to 4.0 fps for the 2001 season.

South Spillway or B-branch Fishway and the **North Spillway or Cascades Island Fishway** are part of the original fishway system with detailed write-up of its operation in the Bonneville Dam section of the FPP. Gravity flow water is supplied from the forebay, through the diffusion system into the lower end of the fish ladder. Both fishways have similar main entrances (design-wise) with side and downstream entrances that operate as continuously open free-flowing vertical slots. Adjacent to each entrance is a spillbay (1 or 18) that

is operated at a minimum of 4 to 6 inches open and passes about 1 kcfs of water. Each main entrance is operated to meet the head differential criteria of 1.0 to 2.0 ft with a targeted head differential of 1.5 ft.

During 2001, the B-branch entrance operated within a range of 1.3 to 1.7 ft, while the Cascades Island entrance operated within a range of 1.3 to 1.8 ft. Head differentials for the B-branch and Cascades Island entrances were within criteria range during the entire fish passage season. The supply valves worked satisfactorily at each branch. The B-Branch and Cascades Island fishway entrances were on manual for the season; no computer readings were available in 2001. **On the initial inspection, the B-Branch auxiliary water was shut down to allow for the installation of antennas in the forebay.**

Fish Ladder: Depth of water measured over the Bradford Island fish ladder weirs ranged from 0.8 to 1.3 ft. The respective readings should be 0.9 ft and 1.1 ft to equate to about 1.0 ft and 1.3 ft of water down the individual A- and B-branch fish ladders. The depth of water measured at A- B-Branches ranged from 0.7 ft to 1.4 ft during the year. Similar to November 2000, the water depth was only 0.7' to 0.8' at the three locations in November 2001; all readings were well below acceptable levels (0.7 ft reported in the A- and B-Branch Ladders). The depth of water measured over the Cascades Island fish ladder weirs ranged from 1.0 ft to 1.3 ft, all readings were at satisfactory levels. The fish ladder exit at Bradford Island was reported clear of debris on 6 of 8 inspections during the 2001 fish passage season.

Powerhouse 2 Fishway

Fish turbines F1 and F2 were operated during the fish passage season and supplied about 5,000 cfs of water to the main entrances and orifice gates along the powerhouse collection channel. During the evenings (approximately midnight to 3 a.m.) the fish units were shut down (as necessary) to float debris off the trashracks and reduce the head differential across the racks. This action was completed to keep the head differential across the trashracks in an acceptable range. **Note** that shutting down the fish turbines would not change the fish ladder operation but would change the attraction flows from the main entrance gates for the 3-hour time period.

Head differentials measured at the four main entrances ranged between 0.9 ft and 1.8 ft at the North entrance gates with the South entrance gates reporting less than the 1.0 ft minimum on 5 of 8 inspections. I subsequently learned that the sliding staff gages were not seated and read from 0.3 to 0.5 ft less than actual elevation in the channel (not tailwater elevation). Gate depths ranged between 6.0 ft and 13.3 ft for the season. Readings were close to 13.0 ft or more for the March and June inspections, with the July through September inspections ranging from 6.0 to 9.0 ft when tailwater elevations prevented the gate from going deeper; the gate was on sill (elevation 1.0 ft). The project can normally keep gate depths within criteria range (about 13.0 ft submerged) under all tailwater elevations above elevation 14. The panel readings varied from on site readings made by the inspectors on several inspections.

Table 1. Pertinent Data for Fish Facility Inspections in 2001 at BONNEVILLE DAM.

CRITERIA ITEMS		DATE OF INSPECTION							
Bradford Island Fishway		28-Mar	25-Apr	7-May	21-Jun	16-Jul	22-Aug	7-Sep	7-Nov
Bradford Island Entrances									
Criteria: (Head Differ. = 1.0-2.0 ft); (Weir Depth + 8 ft or >); (Depth over ladder weirs = 1-1.3 ft); (Velocity + 1.5-4.0 ft)									
Head at A-Branch entrance	ft	2.1	1.8	1.9	1.1	1.6	1.4	1.3	1.8
Depth over Gate 64/65	ft	8.4	8.1	8.3	8.2	3.9	6.5	4.9	8.3
Head at South ph entrance	ft	1.4	1.2	1.2	1.1	1.5	1.3	1.8	1.3
Depth over Gate 1/2	ft	9.1	8.8	7.8	7.7	4.0	5.2	3.5	8.0
Channel Velocity	fps	2.7	2.8	1.5-2.8	2.6	2.6	1.3-2.6	2.2	2.8
Depth- Bradford Is. ladder weirs	ft	1.1	0.9	1.0	1.3	1.3	1.0	1.0	0.8
Depth - A-Branch ladder weirs	ft	1.1	1.1	0.9	1.4	1.3	1.1	1.1	0.7
Exit clean (Yes or No)		no	yes	yes	yes	yes	no	yes	fair
B-Branch Entrance									
Head at B Branch entrance	ft	0.0	1.3	1.6	1.5	1.6	1.7	1.6	1.4
Staff gages clean		yes	yes	yes	yes	yes	yes	yes	yes
Depth over ladder weir	ft	0.9	1.0	unk	1.3	1.3	1.0	1.0	0.7
Cascades Island Entrance									
Head at main entrance	ft	1.6	1.4	1.3	1.8	1.7	1.8	1.6	1.3
Staff gages clean		yes	yes	yes	yes	yes	yes	yes	yes
Depth over ladder weir	ft	1.0	1.0	1.0	1.2	1.2	1.3	1.1	1.0
Washington Shore Fishway									
WA Shore Entrance:									
Depth over entrance weir (Criteria = 13.0 ft or >)									
NUE	ft	13.2	11.3	12.3	13.3	7.2	9.4	6.8	11.1
NDE	ft	13.1	11.4	12.3	12.7	6.7	9.4	6.3	11.1
SUE	ft	12.8	11.7	11.9	13.0	6.5	9.4	6.3	11.0
SDE	ft	13.0	11.5	12.2	12.2	6.0	9.4	6.2	11.0
Head at entrance (Criteria = 1.0-2.0 ft)									
NUE	ft	1.2	1.8	1.3	1.6	1.4	1.1	1.2	1.6
NDE	ft	0.9	1.6	1.3	1.4	1.3	1.0	1.1	1.6
SUE	ft	0.8	1.0	0.6	1.0	0.9	0.7	0.9	1.0
SDE	ft	0.7	1.1	0.5	1.3	0.9	1.0	0.8	1.0
Depth over ladder weir (67)	ft	1.0	1.2	1.0	1.3	1.6	1.3	1.2	1.0
Channel Velocity (Elect. Meter)		1.4	2.1	1.5-2.1	OOS	OOS	OOS	OOS	OOS
Ladder exit clean		yes	yes	yes	yes	yes	yes	yes	yes
Staff gages clean		yes	no	yes	yes	no	yes	yes	yes
Comment # (if applicable)		1	2	3	4	5		6	

Comments:

1. The AWS was shut off for B-Branch entrance to allow for the installation of antennas in the forebay.
The differentials were low in the B2 fishway entrance gates. B-Branch and Cascade Island Fishway Entrances on Manual.
2. Inspector observed 5 sea lions in spillway and B2 tailwater; B1 orifice gates closed for study.
3. Head differential low at SUE/SDE; Lots of stryofoam in gatewells-Tribal fishery floats.
4. Water velocity meter out of service through end of season.
5. Tailwater elevations were extremely low, causing gate depths to be minimal.
6. Same comment as #5 above.

The velocity meter located in the north end of the WA shore powerhouse collection channel worked during the March through May inspections with readings from 1.4 to 2.1 fps. Water velocities were on the low end of the spectrum (minimum velocity should be 1.5 fps).

Fish Ladder: The fish ladder exit and the serpentine section of the fish ladder were reported clear of debris during 2001. The depth of water measured over the WA fish ladder weirs was (1.0-1.6 ft). The July inspection showed the water depth at 1.6 ft over the weirs; all other inspections were within satisfactory range during the inspection season.

Overall, fish passage at Bonneville Dam during 2001:

- Low tailwater conditions were present at the project from July through October and on many occasions, the gates were on sill and minimal gate depths were present with tailwater conditions that existed this year at the Old and New Powerhouse fishway entrances.
- The fish turbines at the WA fishway worked throughout the entire fish passage season in 2001. Any OOS time was during the nighttime hours to clear trash from racks.
- The low flows brought reduced amounts of debris and the fishways were relatively clear of debris for most of the year. The floating grasses are becoming a problem during summer and fall months.
- Adult salmon returns were at record-high numbers for the project and no apparent problems were seen at the fish ladders and through to the exits from the ladders.
- The New powerhouse can be operated independent from the Old powerhouse, and as a result, the New powerhouse was prioritized for operation this season. This resulted in many thousands of salmon passing through the WA fish ladders; however, passage appeared satisfactory with the exception of when trapping occurred and fish numbers were very high below the leads to the adult fish laboratory.

Areas that still require improvement are:

- The project should modify its fishway control panel at ph2 and assure that the controlling system is calibrated with the on-site readings as well as in the Control Room of the dam. The system should be run on auto as much as possible rather than manual.
- The project should place a gage in/on the south shore weirs at ph1 so that an on-site elevation reading can be taken and then compared to the computer reading to assure the gates are calibrated correctly.
- There were inspections when staff gages were unreadable or were not calibrated prior to the fish passage season (WA shore South Channel Staff Gages).
- Keep debris from the new powerhouse fish turbine units and trashracks. This remains a problem at the project. Throughout 1998-2001, the fish turbines were taken off-line for about three hours per evening as needed to reduce buildup of debris on the trashracks. There should be a better solution to the problem than shutting down auxiliary water flow.
- A Task Group has been established to update criteria/protocol for operation of the Adult Laboratory at the WA shore fish ladder; this will include recommendations to improve the trap and associated equipment.

THE DALLES DAM (see photos page 46)

The Dalles Dam was completed in 1957 with 22 main turbine units and two smaller turbine units. The two smaller turbines, Units F-1 and F-2, were part of the original construction and supply water to the Oregon fishway. The spillway is located between the powerhouse and North shore fishway and incorporates 20 spillbays to pass excess or designated flow past the project. The spill basin is shallow and no fliplips are installed to dissipate the spilled flow.

Approximately 5,000 cfs of water was originally distributed from these small turbines to the East, West, and South fishway entrances as well as to the orifice gates along the powerhouse collection channel. With the closure of the Orifice Gates along the powerhouse collection channel in 2000, about 4,200 cfs flow is required to meet depth and head criteria at these main entrances. In the early 1990s, Wasco County PUD installed a small turbine on the old auxiliary water supply at the WA shore fishway. This turbine normally supplies about 800 cfs through the diffusers to the operating entrance, usually Gate N-1.

Doug Case, Oregon Department of Fish & Wildlife (ODFW) inspector for the 2001 fish passage season, completed nine-fishway inspections beginning on March 27 and ending on October 12. Results of the inspections are discussed below and listed in Table 2.

East Fishway Inspections

The East fishway entrance gates (E-2 and E-3) were submerged 8.0 feet or more on all nine inspections (range was 8.6 ft to 13.1 ft; average depth = 11.7 ft). Head differentials ranged from 0.7 ft to 2.2 ft. Fish Turbine F-2 was temporarily OOS for testing of occlusion plates in the forebay with low head differential the result on the initial March inspection. Normally, the East fishway entrances were found operating in satisfactorily criteria range during the inspections completed in 2001.

The channel velocity was taken via a continuous recording unit at the eastern end of the powerhouse collection channel and then estimated by the inspector at the mid-point and western end of the channel. Water velocity in the collection channel ranged between 1.0 fps and 3.5 fps throughout the season. The low velocity reported in the March inspection was due to Fish Turbine F-2 being temporarily OOS.

The **West** fishway entrances (W-1 and W-2) were submerged 8.0 feet or more on all inspections during 2001. The gate depths ranged from 8.0 ft to 9.5 ft. Head differential readings ranged from 0.9 ft to 1.7 ft. Throughout the season all head differential and gate depth readings met the criteria at the West Entrances with exception of the temporary outage of F-2 on March 27.

The **South** fishway entrances (S-1 and S-2) were operated close to criteria regarding head differential with exception of the initial inspection when only one fish turbine was operating and 0.2 ft head differential was reported (short-term condition). The project met gate depth criteria of 8.0 ft or more on 5 of 9 inspections. In previous years, the project appeared reluctant to change or calibrate their sensors at this entrance; however, during the June 2001 inspection, the project biologist and an electrician accompanied the ODFW inspector and myself to check calibration of this entrance. A water level sensor was used to ascertain calibration of the readings. The Selsyns Gage tape reading from the channel had consistently been reading low (based on review of previous inspections). The Selsyns tape was pulled, and we found that it was twisted and kinked near the bottom. This tape was later repaired and placed back into operation.

Fish Ladder: The picketed leads located at the OR fish counting station had some debris on 5 of the 9 inspections. The depth of water over the fish ladder weirs ranged between 1.1 and 1.4 ft during the season and was acceptable during the 2001 inspection season. The exit was reported clear of debris on 7 of 9 inspections.

North Shore Fishway Inspections

At the WA fishway, Wasco County Public Utility District operates a fish turbine that supplies flow through diffusion gratings and to the main fishway entrance. The turbine and related fishway equipment operated satisfactorily throughout the 2001 fish passage season. Normally, flow has been sufficient to meet gate depth and head differential criteria at the North Shore.

The North entrance gate, N-1, was operated throughout the fish passage season. Gate depths ranged from 8.7 to 9.0 feet for the season and head differential ranged from 1.1 to 1.4 ft. The WA fishway operated satisfactorily throughout the fish migration and met criteria standards on all inspections. All cables and equipment operated without failure this season.

Fish Ladder: The ladder exit was reported with debris on 1 of 9 inspections. A large head differential existed at the exit as well as the PUD trashrack during the March inspection. The picketed leads were reported with some buildup of debris during 6 of the 8 inspections. The main problem is linked to sticks and other debris building on the picketed leads. The depth of water recorded over the ladder weirs also showed the fish ladder in proper criteria within a range of 1.0 to 1.3 ft for the season.

Overall, the fish facility inspections showed The Dalles Project operating close to acceptable criteria throughout the fish passage season. Record numbers of adult salmon species passed the project with little or no known delays caused by fishway operations. One key item at The Dalles Dam was solved in 2000; i.e., water velocity was increased in the eastern end of the powerhouse collection channel by the closure of the Orifice Gates. This closure changed hydraulics in the channel and improved water velocity through the collection channel to where it is now within the desired range. Also, closure of the orifice gates resulted in availability of more water to pass to the East and West fishway entrance gates, and should improve distribution of flow to the South fishway entrances.

Some areas of concern are listed below.

- **The PLCs and any sensor or gage should be checked to assure calibration of the readings at the main fishway entrances.** For most or all of the season, the PLCs did not work correctly. A copy of the ODFW inspector's readings of the elevations at the South Entrance using the Selsyns tapes, PLC, and the sensor tape illustrates differences that can occur when a Selsyns tape became kinked and was off by nearly 0.3 ft. This tape was likely kinked all of the 2000 season as well.
- The COE should assure that the PUD trashracks are cleaned on a regular basis; on several occasions, excess trash was matted on or floating at the PUD intake. This cleaning should be moved to higher priority for the project.
- The exit from the North shore fish ladder was not cleaned prior to the fish passage season; this should be an annual part of the winter maintenance season as well as routinely scheduled cleaning through the fish passage season.
- Late season buildup of floating grasses appears to be affecting head differential across picketed leads, fishway exits, and other areas where water is pulled into fishways.

Table 2. Pertinent Data for Fish Facility Inspections in 2001 at THE DALLES DAM.

CRITERIA ITEMS		DATE OF INSPECTION								
SOUTH SHORE FISHWAY		**27-Mar**	**11-Apr**	**1-May**	**5-Jun**	**2-Jul**	**8-Aug**	**21-Aug**	**14-Sep**	**12-Oct**
East Entrance:										
Depth over entrance weir										
E-1 (gate set at elev. 83.5 ft)	ft									
E-2 (crit. = 8 ft or >)	ft	12.6	13.1	12.7	12.3	11.1	8.6	10.9	11.9	11.6
E-3 (crit. = 8 ft or >)	ft	12.6	13.1	12.3	12.0	11.1	10.9	10.9	11.6	10.6
Head at main entrance (crit. = 1-2 ft)	ft	0.7	1.8	1.8	1.3	1.5	2.2	1.8	1.4	1.4
Depth over ladr. weir (crit. = 1-1.3 ft)	ft	1.2	1.2	1.2	1.3	1.4	1.1	1.2	1.1	1.3
Channel Velocity (crit. = 1.5 - 4.0 fps)	fps	1-1.5	1.5-2.5	2.3	1.5-2.5	2.1	3.3	3.5	1.8	1.7
Ladder exit clean (yes or no)		yes	no	yes	yes	no	yes	yes	yes	yes
Selsyns/PLC operating (yes or no)		yes	yes	yes	yes	yes	no	no	no	no
Picket leads clean (yes or no)		yes	no	yes	no	no	no	yes	no	yes
West Entrance:										
Depth over entrance weir										
W-1 (crit. = 8 ft or >)	ft	8.6	8.0	9.5	9.3	9.0	9.3	8.7	8.0	8.2
W-2 (crit. = 8 ft or >)	ft	8.6	8.2	9.5	9.4	9.0	9.3	8.7	8.1	8.2
Head at main entrance (crit. = 1-2 ft)	ft	0.9	1.7	1.6	1.3	1.4	1.1	1.0	1.1	1.1
South Entrance:										
Depth over entrance weir										
S-1 (Crit. = 8 ft or >)	ft	9.5	8.0	8.0	8.1	6.4	8.7	6.6	8.0	7.4
S-2 (Crit. = 8 ft or >)	ft	9.7	8.2	6.5	7.7	8.4	8.9	7.8	9.3	8.2
Head at main entrance (Crit. = 1-2 ft)	ft	0.2	1.0	1.4	0.8	1.4	1.3	1.6	1.0	1.2
NORTH SHORE FISHWAY										
North Shore Entrance:										
Depth over entrance weir										
N-1 (crit. = 8 ft or >)	ft	9.0	8.9	9.0	9.0	8.8	8.9	9.0	9.0	8.7
Head at main entrance (Crit. = 1-2 ft)	ft	1.4	1.4	1.3	1.4	1.1	1.4	1.2	1.3	1.1
Depth over ladr. weir (Crit. = 1-1.3 ft)	ft	1.0	1.1	1.0	1.2	1.3	1.0	1.0	1.0	1.0
Ladder exit clean		no	no	yes	yes	yes	yes	yes	yes	yes
Selsyns operating		yes	yes	yes	yes	yes	yes	yes	yes	yes
Picket leads clean		no	no	no	no	no	yes	yes	yes	yes
PUD trash rack clean (yes or no)		no	no	no	yes	no	yes	--	yes	yes
Spill Pattern w/i Criteria (yes or no)		n/sp	n/sp	n/sp	yes	n/sp	yes	yes	n/sp	n/sp
Comment Number (if applicable)		1	2		3		4	5	6	

Comments

1. Fish Turbine F-2 OOS for testing of occlusion plates in forebay; low head differentials were result; Calibration of PLCs required; PUD trash racks required cleaning; North picket leads at count station req. cleaning.
2. Same comments for PLCs and PUD trash racks.
3. Calibration of S Spillway Entrance readings made; Selsyns tape twisted/kinked near bottom.
4. Calibration of E and Spill Entrances required; The COE should use Sensors on inspections.
5. Count Windows clean/excellent; COE should continue working on calibration of PLCs.
6. E. pickets cleaned; COE should complete work on their PLC system controls.

JOHN DAY DAM (see photos page 47)

John Day Dam is a COE operated project that went on-line for power production in 1968 with 16 main turbine units and a spillway equipped with 20 spillbays. The major change to the project has been the addition of fliplips into the spillbays. This has allowed the project to spill additional flow without greatly increasing dissolved gas levels at the project.

Three turbine driven pumps pull water from the tailwater of the dam and this water is incorporated into the water supply for the Oregon shore adult fishway. This water is supplied through the diffuser system where it exits out one main entrance on the south shore, two main entrances at the north end of the powerhouse, and 10 floating orifice gates along the collection channel. The project is able to operate two of the three pumps to meet criteria levels of operating the main entrances as well as the floating orifice gates along the powerhouse collection channel. Six electric pumps are operable on the WA shore to supply water to the diffusers located at the lower end of the fish ladder; however, a maximum of only four pumps (normally three pumps) can operate at any one time at the north shore. Beginning in 2000 and continuing in 2001, one main entrance at the north end of the spillway is now operating rather than two as in previous years.

Doug Case, ODFW, completed nine inspections of the fish facilities from March 27 through October 12 at the John Day project. Table 3 lists the criteria items and the inspection dates for the John Day project.

South (Oregon Shore) Fishway Inspections

The south shore fishway operated gate SE-1 throughout the season. The head differential measured at the main entrance was between 1.0 and 2.0 ft on every inspection (range = 1.1 to 1.4 ft), with the weir depth ranging between 7.6 ft and 8.5 ft. The gate depth was 8.0 ft or more on eight of nine inspections. Overall, entrance conditions at Gate SE-1 should have provided satisfactory fish passage during the nine inspections.

The north powerhouse entrance gates, NE-1 and NE-2, were operated within criteria for head differential, range = 1.0 to 1.4 ft during the inspections. The gate depths ranged from 7.7 ft to 8.6 ft with gate depth less than 8.0 ft on the August 8 inspection; however, with the gates submerged 7.7 ft and head differential of 1.4 ft, sufficient flow was available to provide good attraction flows for approaching adult fish.

Water velocity along the powerhouse collection channel ranged from 1.8 to 2.3 fps as measured at the velocity meter installed near the south end of the channel. The electronic velocity meter worked satisfactorily during the 2001 fish passage season.

Fish Ladder: The exit from the fish ladder was clear of debris throughout the season, and staff gages were reported as clean. The picketed leads had some amount of debris recorded during the first four inspections. Also, a large Styrofoam float was observed in the Oregon ladder (March inspection) and a small log and sticks were jammed in the serpentine pool weir slot between pools 17/18 in the April inspection. As noted in all previous seasons, fish are still jumping in the upper section of the fish ladder during the late fall; however, modifications made to the fish ladder improved passage conditions in that section of the ladder when compared to previous years. The depth of water measured over the ladder weirs ranged between 1.0 ft and 1.3 ft for the season and was within the criteria range of 1.0 ft ± 0.1 ft during the non-shad period and 1.3 ft ± 0.1 ft during the shad passage season.

North Shore Fishway Inspections

The criteria settings for the north shore fishway entrances were changed prior to the 2000 season. Only one entrance gate, N-2, is now operated. Gate N-2 should be submerged 8.0 ft or more below tailwater, with the head differential maintained between 1.0-2.0 ft (targeted 1.5 ft). The minimum 8.0-ft gate depth criterion was met on all inspections; the depths ranged from 8.0 ft to 9.0 ft. Aside from the initial inspection when testing was occurring, head differentials were normally found operating at acceptable criteria range

throughout the season. On two occasions, the "head" was recorded at 0.9 ft; however, gate depth was nearly 9.0 ft, so flow appeared sufficient during the inspection. For the season, the gate depth and head differential readings resulted in the entrances either meeting criteria or being very close on all inspections during the 2001 inspection season.

Fish Ladder: The exit from the ladder was reported clear of debris on all inspections. The picketed leads were noted with sticks and other debris on one of the nine inspections. The picketed leads had 0.2 to 0.3 ft differential on three inspections indicating that debris was building up on the racks. Depth of water over the fish ladder weirs ranged from 1.0 ft to 1.3 ft, all satisfactory readings.

Overall, the main entrances at the Oregon and the Washington fishways were operated very close to criteria during the 2001 fish passage season. Record numbers of adult salmon passed the project with no apparent delays or problems with satisfactory migration conditions at and through the dam this season. Areas of concern based on observations from the inspections are listed below.

- Fish jumping/leaping (mainly steelhead) in the exit section of the fish ladders at John Day Dam still occurs; however, it was improved when compared to years prior to 2000/2001. Hydraulic conditions should be improved to keep fish moving throughout the upper section of the north and south fish ladders (this has been a continuing recommendation for many years).
- The passage of adult fish through the north shore counting station has been and continues to be a problem, with a high percentage of fish falling back through the counting window (especially late summer and fall run fish). A modification of the counting station is required. During the past few seasons, there has been a large fish count differential between The Dalles Dam, John Day Dam, and McNary Dam. Research of the problem should be continued to find the reason why the differential exists.
- Calibration of the FSC Board and the LED Readout should be completed prior to each passage season and maintained through the year.
- A drain above the Oregon fish ladder was dripping into the fish ladder from the roadway located above the ladder. The project was made aware of the drain, and it was repaired (re-routed) during the 2002 winter maintenance season.

Table 3. Pertinent Data for Fish Facility Inspections in 2001 at JOHN DAY DAM.

CRITERIA ITEMS		DATE OF INSPECTION								
SOUTH SHORE FISHWAY		**27-Mar**	**11-Apr**	**1-May**	**5-Jun**	**2-Jul**	**8-Aug**	**21-Aug**	**14-Sep**	**12-Oct**
South Shore Entrance:										
Depth over entrance weir										
SE-1 (Crit. = 8 ft or >)	ft	8.2	7.6	8.5	8.4	8.5	8.5	8.4	8.4	8.0
Head at SE-1 (Crit. = 1-2 ft)	ft	1.1	1.1	1.3	1.2	1.3	1.1	1.4	1.4	1.4
Dep. over ladr. weir (Crit.=1.0 +/-0.1)										
ft [normal] & 1.3 ft shad season)	ft	1.0	1.0	1.0	1.2	1.3	1.0	1.0	1.0	1.0
Channel Veloc (Criteria = 1.5 - 4.0 fps)	fps	2.0	1.8	2.1	2.3	2.1	1.8	2.1	1.8	1.8
Ladder exit clean (Yes or No)		yes	yes	yes	yes	yes	yes	yes	yes	yes
Staff gages clean (Yes or No)		yes	yes	yes	yes	yes	yes	yes	yes	yes
Picket Leads Clean (Yes or No)		no	no	no	no	yes	yes	yes	yes	yes
North Powerhouse Entrance:										
Depth over entrance weir										
NE-1 (Crit. = 8 ft or >)	ft	8.3	8.2	8.4	8.2	8.4	7.7	8.3	8.6	8.2
NE-2 (Crit. = 8 ft or >)	ft	8.1	8.1	8.4	8.2	8.3	7.8	8.3	8.5	8.3
Head at NE-1&2 (Crit. = 1-2 ft)	ft	1.1	1.0	1.3	1.3	1.2	1.4	1.1	1.1	1.3
Staff gages clean (yes or no)		yes	yes	yes	yes	yes	yes	yes	yes	yes
NORTH SHORE FISHWAY										
North Shore Entrance:										
Depth over entrance weir										
N-2 (Crit. = 8 ft or >)	ft	7.8/8.9	8.0	8.7	8.8	8.7	8.6	9.0	8.9	8.0
Head at N-2(Crit. = 1-2 ft) Targ - 1.5'	ft	0.6	1.1	1.1	1.0	1.1	1.0	0.9	0.9	1.3
Depth over ldr weir (Crit.=1.0 +/-0.1)	ft	1.0	1.1	1.1	1.3	1.3	1.0	1.0	1.0	1.0
Ladder exit clean		yes	yes	yes	yes	yes	yes	yes	yes	yes
Staff gages clean		yes	yes	yes	yes	yes	yes	no	yes	yes
Picket leads clean		yes	yes	yes	yes	no	yes	yes	yes	yes
Comment number (if applicable)		1	2		3		4	5		

Comments:

1. 2-N Shore Entrances open for PLC testing; Large stryofoam float in S ladder (tribal).
2. A small log and sticks are jammed in the serpentine pool weir slot between pools 17/18 in S fish ladder.

FSC Board Readings do not match up with staff gage readings for NE and SE powerhouse entrances.

3. Drain above OR fish ladder should be rerouted to preclude water from road dropping in fish ladder.
4. The Project fishways were temporarily out of criteria due to diving at project to check diffuser gratings, etc.
5. Site inspection completed with Salmon Corps personnel.

MCNARY DAM (see photos page 48)

McNary hydroelectric project is a COE operated dam completed in 1953. The project incorporates 14 main turbine units and 22 spillbays. The end two spillbays per side are split-leaf gates and do not have fliplips installed below them. Note: fliplips will be placed in these end bays prior to the 2002 season, and the split-leaf gates modified as well. The OR and WA shore fish ladders incorporate full overflow weirs and have submerged orifices in each weir. The fish ladders carry at least double the Q as the newer fish ladders built at other COE dams. On the OR fishway, three large electric fish pumps drawing water from the tailrace of the dam plus about 1,000 cfs of gravity flow from the forebay, supply water to the main entrance gates located at each end of the powerhouse. Along the powerhouse collection channel, 12 floating orifice gates supply about 60 cfs each to the tailwater to attract adult fish to the channel. Initially, the project operated 30 of these gates along the powerhouse, but this total was reduced to the present 12 in the mid-1980s. One other major change on the WA shore fishway was completed in the 1990s. The water supply for the WA fishway was changed from the pressurized system to a non pressurized one. Wasco/Klickitat PUDs installed a small turbine on the water supply from the forebay that produces electricity for the PUD and also supplies flow (about 1,600 to 1,700 cfs) to meet gate depth and head differential requirements for the two main entrance gates.

Larry Swenson, NMFS, inspected the fish facilities at McNary Dam on eight separate occasions between April and November 2001. Results of the inspections are discussed below with Table 4 listing data collected from the inspections. A copy of the computer-generated Status Report of the fishway readings was normally obtained by the inspector at the beginning of the inspection and compared with the field data taken at the main entrances. The site readings and the computer-generated report of the fishway readings normally did not vary more than 0.3 ft and calibration was not required.

The project can normally meet criteria standards operating with two of the three pumps at the OR fishway. When three pumps operate, the angle open normally ranges between 20-24° while the blade angle is increased to 28 to 32° when two pumps operate. In addition to the pumped and gravity-flow water, about 350 to 400 cfs of water from the juvenile bypass system is added to the north end of the powerhouse. Wall screens are present to exclude adult fish from entering this water source.

No spill was present during fish facility inspections; however, a small amount of spill occurred in May.

South Shore (Oregon) Fishway Inspections

During 2001, the main entrances at the south shore (SFEW-1 & 2) were reported within the criteria range of 9 ft or greater gate depth and 1.0 ft to 2.0-ft head differential on all 8 inspections of the fish facilities. The gate depths ranged from 9.0 ft to 9.5 ft, with head differentials ranging from 1.3 ft to 1.6 ft. The north powerhouse entrances (NFEW-1 & 2) were reported within the required criteria as gate depths ranged from 9.7 ft to 10.1 ft and head differentials ranged from 1.5 ft to 1.8 ft. On the initial inspection, the project was repairing the gate elevation instrumentation at the North Powerhouse entrances; the system worked satisfactorily after this instrumentation was completed.

Water velocities were recorded via an electronic meter installed downstream of the junction pool and upstream of ph turbine unit #1. Surface velocity was estimated at the northern end of the channel by timing a wood chip or floating object a given distance along the channel. Basically, water velocity was between 0.5 fps and 1.7 fps at the south end of the collection channel and increased to 2.0 to 3.2 fps at the northern end of the channel. We were uncertain whether the electronic reading was faulty or whether the location in the channel was causing the large fluctuations in the readings this year.

Fish Ladder: The picketed leads located at the OR fish ladder count station were reported clear of debris during the inspections. The exit from the fish ladder was reported with excess debris on two of the 8

inspections. The depth of water reported over the OR fish ladder weirs ranged from 1.0 ft to 1.3 ft and was within acceptable range during the season.

North Shore (Washington) Fishway Inspections

The WA shore fishway entrances, WFE-2 and WFE-3 were submerged from 8.6 ft to 9.4 ft with head differentials at the entrances ranging from 1.2 ft to 1.5 ft. The gate depths and head differentials were operated within acceptable criteria range throughout the season, i.e., greater than 8.0 ft gate depth with head differential from 1.0 ft to 2.0 ft. The computer-generated report gave fairly close correlation with the on-site readings.

Since the completion of the PUD turbine installation in 1998, inspections of the fish facilities have shown a marked improvement relating to gate depths as well as head differentials reported at the site when compared to data recorded from FPC inspection reports from 1994-97. For example, from 1994-97, the average gate depth was about 8.6 ft with an average head differential of 1.25 ft, and from 1998-00, Gates WFE-2 and WFE-3 readings increased to 9.5 ft average gate depth and 1.4 ft average head differential. The 2001 inspection data showed the average gate depth at 9.1 ft with the head differential at 1.6 ft.

Fish Ladder: The fishway exit was reported with some debris (tumbleweeds or other grasses) on one inspection. The picketed lead section located at the counting station in the WA fish ladder was reported clear of debris during this inspection season. The depth of water recorded over the ladder weirs ranged from a low of 0.9 ft (9/25) to 1.1 ft during the inspection season. The project normally cleared the leads on Monday and Thursday of each week to keep the debris from building on the picketed leads.

Overall, the adult fishways operated close to the criteria established for the WA and OR fish passage facilities with the main entrances operating in acceptable criteria during the adult fish passage season. Some problem areas that exist or should be investigated further are:

- The telescoping gate at the upstream end of the exit channel may block the exit orifice; this area of the fishway should be assessed for improvement by the project.
- The electronic velocity meter may be giving faulty readings and potentially should be relocated by the project.

The inspections made of the **juvenile fish passage system** showed some continued problem areas that were present during the inspection season.

- Western Grebes were again reported in the juvenile bypass channel in 2001. The project should continue efforts to keep these birds away from the gatewells and bypass channel where possible, as they are very effective predators on the juvenile fish in these enclosed areas.
- The District should improve procedures for reducing amounts of floating grasses away from the juvenile bypass screening systems.

Table 4. Pertinent Data for Fish Facility Inspections in 2001 at MCNARY DAM.

CRITERIA ITEMS		DATE OF INSPECTION							
SOUTH SHORE FISHWAY		12-Apr	4-May	25-Jun	24-Jul	23-Aug	25-Sep	23-Oct	9-Nov
South Shore Entrance:									
Depth over entrance weir (Criteria: 9 ft or > gate depth at SFEW-1,2 & NFEW-1,2)									
SFEW-1	ft	9.0	9.1	9.0	9.5	9.5	9.3	9.5	9.3
SFEW-2	ft	9.0	9.1	9.0	9.5	9.5	9.3	9.5	9.3
Head at SFEW-1,2 (Crit.= 1-2 ft)	ft	1.3	1.4	1.5	1.3	1.5	1.4	1.6	1.6
Dep. over ladr. weir(Crit.= 1-1.3')	ft	1.3	1.0	1.0	1.1	1.0	1.0	1.1	1.1
Channel velocity (Crit.= 1.5-4.0 fps)	fps	1.7-2.4	1.1-2.3	0.5-2.0	0.8-2.1	0.5-3.2	0.8-2.8	0.5-2.4	0.7-2.7
Ladder exit clean		yes	yes	yes	no	yes	no	yes	yes
Picket leads clean		yes	yes	yes	yes	yes	yes	yes	out
Orifice Gates Operating - 12		ok	ok	ok	ok	ok	ok	ok	ok
Pumps Operating & degrees open									
North Powerhouse Entrance:									
Depth over entrance weir									
NFEW-2	ft	9.9	9.8	10.1	9.8	9.9	9.7	9.9	9.7
NFEW-3	ft	unk	9.8	10.1	9.9	9.9	9.7	9.9	9.7
Head at NFEW-2&3 (Crit. = 1-2 ft)	ft	1.5	1.7	1.7	1.5	1.7	1.7	1.6	1.8
WA.SHORE FISHWAY									
North Shore Entrance:									
Depth over entrance weir									
WFE-2 (Crit. = 8 ft or >)	ft	9.2	9.3	8.6	9.4	8.8	9.0	9.0	9.4
WFE-3 (Crit. = 8 ft or >)	ft	9.2	9.3	8.6	9.4	8.8	9.0	9.0	9.4
Head at WFE-2&3 (Crit. = 1-2 ft)	ft	1.5	1.6	1.6	1.5	1.7	1.6	1.6	1.5
Dep. over ladr. weir (Crit. = 1-1.3 ft)	ft	1.1	1.0	1.0	1.0	1.0	0.9	1.0	1.0
Ladder exit clean		yes	yes	yes	yes	yes	yes	yes	Weeds
Picket leads clean		yes	yes	yes	yes	yes	yes	yes	out
Comment number (if applicable)		1		2		3	4		

Comments:

1. The telescoping gate at the u/str end of the exit channel may block exit orifice; being investigated. Gate elevation instrumentation was inoperative at NFE and project was fixing the problem.
2. About 62 Western Grebes were in forebay; 5-6 were under deck grating at d/str end of juvenile separator.
3. OR shore fish counting window and backboard needed cleaning; the velocity reporting at the S end of the ph may be off, I.e., gives a faulty reading or it is poorly located where flows in the channel fluctuate frequently.
4. Trash, including cigarette butts and paper in Gatewell 6A; higher than normal head differential across some VBSs.

ICE HARBOR DAM (see photos page 49)

Ice Harbor Dam was the initial dam constructed in the lower Snake River and was completed in 1961. The COE-operated project has six main turbine units and ten spillbays to pass water at the dam. A recent change at the project has been the addition of fliplips in the spillbays and a training wall (completed in 1999) to "straighten" flow on the south end of the spillway. The adult fish passage facilities consist of two separate water supply systems for the south and north shore fishways. Attraction flow to the south fishway is supplied by up to eight electric pumps and about 200 cfs flow from the juvenile bypass system. Five to 8 fish pumps operate, depending on the tailwater elevation. Under most river flow conditions, the project can maintain the fishway within acceptable criteria for gate depth and head differential. Three electric fish pumps supply attraction water to the north shore fishway with the pumped flow at times less than required to meet criteria conditions.

Steve Richards, WDFW completed 6 adult fishway inspections at Ice Harbor Dam during the 2001 fish passage season. A seventh inspection was scheduled but not completed due to security and accessibility to the project in September. Details of the inspections are found in Table 5 and the summary of the inspections in the write-up below.

A fishway inspection is completed as follows: The inspector reports into the operations office, obtains hydraulic information including river Q, spill patterns, and turbine operation from the control room. The inspector also receives a computer printout of the elevations of the entrance gates, corresponding head differentials, etc. Comparison of the site readings and the computer system is made to check for correlation of the two systems. Readings should be fairly close between the computer and the on-site elevations, especially during lower flows when tailwater elevations are more stable and spill levels are reduced.

South Shore Fishway Inspections

During the inspection season, eight fish pumps were operated, along with the excess juvenile bypass flow, to supply water to the main fishway entrances and the orifice gates along the powerhouse collection channel. The south shore entrance gate (SFEW-1) was submerged from 7.2 ft to 8.3 ft during the season with the Gate SFEW-1 on sill, 2 of the six inspections, August and October. Head differential measured at SFEW-1 ranged from 1.7 ft to 2.0 ft for the season. Q from this Entrance should have been sufficient with the head reported during the six 2001 inspections.

The north powerhouse entrance gate (NFE-2) has criteria relating to gate depth of 8 ft or > and head differential of 1.0-2.0 ft. Weir depths ranged between 6.1 ft and 11.9 ft for the season. Head differential ranged from 1.1 ft to 1.8 ft. The gate was not on sill during the inspection dates this season. **Head differential was sufficient on all inspections; however, gate depths of 6.5 ft and 6.1 ft were well below the required 8.0 ft**.

Across the powerhouse, 7 floating orifice gates operated throughout the fish passage season. It appeared from the inspections that they worked satisfactorily during 2001. The water velocity in the collection channel was reported from 2.0 to 2.7 fps during the season; all reports were within the desired range.

Fish Ladder: The exit from the fish ladder was reported clear of debris on all inspections; however, head loss measured across the picketed leads indicated that they required cleaning on 3 of the six inspections this season. Gatewells (juvenile fish bypass system) across the powerhouse forebay deck were clear of debris during the season.

North Shore Fishway Inspections

Gate NEW-1 was submerged 8.0 ft or more in depth on the one of six inspections. From June through October, gate depths ranged from 5.6 ft to 6.6 ft. Head differentials were more than the 1.0-ft minimum on 5

of 6 inspections (range = 1.2 - 1.7 ft). A reading of 0.5 ft head differential was recorded for the May inspection, well below the minimum acceptable level of 1.0 ft.

Fish Ladder: The exit from the north shore fish ladder and also the picketed leads at the counting station were reported clear of debris throughout the inspection season. The tailwater staff gage was not usable for calibration or calculation for much of the inspection season.

Overall, the inspections completed during 2001 showed the following items that required action on part of the project to improve fish facilities and inspections.

- We noted discrepancies between the computer printout and the on-site readings and believe that there needs to be better correlation between the two readings. The staff gage on the north shore was not usable all season. Basically, the project should provide good staff gages or an area to take a sensor reading that will be accurate (same issue as in 1999-00).
- **It appeared from the inspection reports that on several occasions, sufficient water was available to meet criteria, but that the control system was not functioning properly to allow mainly gate depth to be within the proper range. The Project should continue to work on its control system and make it workable prior to the fish passage season. The 2001 season appeared to have very similar results as in 1997-00 when flow was sufficient, but the system was not balanced properly between head and gate depth.**

Table 5. Pertinent Data for Fish Facility Inspections in 2001 at ICE HARBOR DAM.

CRITERIA ITEMS		DATE OF INSPECTION						
SOUTH SHORE FISHWAY		**9-Apr**	**16-May**	**27-Jun**	**24-Jul**	**29-Aug**	**25-Sep**	**18-Oct**
South Shore Entrance:								
Depth over entrance weir								
SFEW-1 (Crit. = 8 ft or >)	ft	8.3	7.2	8.0	8.2	7.5		7.8
Head at SFEW-1 (Criteria = 1-2 ft)	ft	2.0	1.8	1.7	1.8	1.9		1.9
Gate on Sill (yes or no)		no	no	no	no	yes		yes
Dep. over ladr. weir (Cr. = 1-1.3 ft)	ft	1.0	1.0	1.1	1.1	1.0		1.1
Channel velocity (Crit. = 1.5-4 fps)	fps	2.4	>2.0	2.5	2.4	2.4		2.7
Ladder exit clean (yes or no)		yes	yes	0.2'	yes	yes		yes
Staff gages clean (yes or no)		yes	yes	yes	yes	yes		yes
Picket leads clean (yes or no)		yes	yes	no	no	yes		no
Pumps Operating (8 available)		8	8	8	8	8		8
North Powerhouse Entrance:								
Depth over entrance weir								
NFE-2 (Criteria = 8 ft or >)	ft	9.4	11.9	7.8	8.3	6.5		6.1
Head at NFE-2 (Criteria = 1-2 ft)	ft	1.1	1.1	1.2	1.8	1.4		1.6
Gate on Sill (yes or no)		no	no	no	no	no		no
Staff gages clean	ft	yes	yes	yes	yes	yes		yes
NORTH SHORE FISHWAY								
North Shore Entrance:								
Depth over entrance weir								
NEW-1 (Criteria = 8 ft or >)	ft	6.7	8.7	6.4	6.6	5.6		6.0
Head at NEW-1 (Criteria = 1-2 ft)	ft	1.2	0.5	1.5	1.3	1.4		1.7
Gate on Sill (yes or no)		no	no	no	no	no		no
Dep. over ladr. weir (Crit. = 1-1.3 ft)	ft	1.0	1.0	1.0	1.1	1.0		1.2
Ladder exit clean		yes	yes	yes	yes	yes		yes
Staff gages clean		no	yes	yes	yes	yes		yes
Picket leads clean		yes	yes	yes	yes	yes		yes
Pumps Operating (3 available)		3	3	3	3	3		3
Comment Number (if applicable)		1	2			3	4	

Comments:

1. The tailwater staff gage at the north shore required repair.
2. Calibration required at the S Shore and N Shore Entrances based on differences between staff gages and computer report.
3. **All gate depths less than required as gates were not on sill.**
4. Steve was unable to complete scheduled inspection due to accessibility to project after Terrorist Attacks at Twin Towers.

LOWER MONUMENTAL DAM (see photos page 50)

The COE completed construction and began operation of Lower Monumental Dam in 1969. Six main turbine units and eight spillbays with fliplips installed on six bays are presently in operation at the dam.

The project incorporates three turbine-driven pumps that pull water from the tailrace and supply water to a conduit that distributes this flow to the diffuser system along the collection channel and the north and south shore collection systems. The south shore fishway has a separate fish ladder, but a separate water supply was not added to that side of the dam. In the early 1990s, about 200 cfs of excess water flow from the juvenile bypass system was also added to the north shore supply diffusers. Normally the juvenile bypass system operates from March through December. Since that time, and with other changes made to the fish pumps, the project can normally meet gate depth and head differential criteria with two pumps.

The adult fish passage facilities at Lower Monumental Dam were inspected six times by Steve Richards, WDFW during 2001. Inspections were from April 9 through October 18; the scheduled September inspection was cancelled due to security issues at the dam and availability of staff to accompany Steve on the inspection. Data from the inspections are reported in the discussion below as well as in Table 6.

North Shore Fishway

The north shore fishway entrance gates, NSE-1 and NSE-2, were operated with gate depths ranging from 8.0 ft to 8.7 ft during the inspections and met depth criterion of 8.0 ft or greater submerged below tailwater elevation for each gate. Head differentials ranged from 1.2 ft to 2.1 ft; all readings were within or near the acceptable range for head differential (criteria = 1.0-2.0 ft).

The water velocity in the collection channel was satisfactory throughout the season. An electronic velocity meter is located in the northern end of the collection channel. For the season, the velocity ranged from 2.0-2.3 fps.

Orifice gates along the collection channel remained closed in 2001. Adult fish can enter the fishway only through the NSE and SPE gates. Evaluation of how fish passage conditions with and without orifice gates operating in the collection channel was accomplished through the adult fish passage studies. No differences or increase in passage times were apparent with the closure of the orifice gates.

The south powerhouse entrance gates, SPE-1 and SPE-2, were operated with gate depths ranging from 6.5 ft to 9.7 ft. The SPEs were on sill during all inspections so no further depth could be attained. Head differentials recorded at the South Powerhouse Gates ranged from 0.9 ft to a high of 1.4 feet.

Fish Ladder: The depth of water over the north shore fish ladder weirs was 1.1 ft on 5 of 6 inspections with the August inspection at 1.0 ft. All readings were acceptable. The differentials reported at the fish ladder exit and at the picketed leads at the fish counting facility were within acceptable ranges. Normally air from a high-pressure conduit bubbles in near the surface of the water of the exit and this keeps debris away from the exit; we noted that the bubbler was not operating during the October inspection and as a result, there was lots of floating debris above the N Shore fishway exit.

Table 6. Pertinent Data for Fish Facility Inspections in 2001 at LOWER MONUMENTAL DAM

CRITERIA ITEMS		DATE OF INSPECTION						
NORTH SHORE FISHWAY		9-Apr	16-May	27-Jun	24-Jul	29-Aug	25-Sep	18-Oct
North Shore Entrance:								
Depth over entrance weir								
NSE-1 (Criteria = 8 ft or >)	ft	8.0	8.2	8.5	8.0	8.7		8.4
NSE-2 (Criteria = 8 ft or>)	ft	8.1	8.2	8.6	8.0	8.7		8.4
Head at NSE-1 & 2 (Crit. = 1-2 ft)	ft	1.6	1.4	1.5	2.1	1.2		2.0
Gate on Sill (yes or no)		no	no	no	no	no		no
Dep. over ladr. weir (Cr. = 1-1.3 ft)	ft	1.1	1.1	1.1	1.1	1.0		1.1
Channel velocity (Crit. = 1.5 - 4 fps)	fps	>2.0	>2.0	>2.0	>2.0	>2.0		2.3
Ladder exit clean (yes or no)		yes	yes	yes	yes	yes		yes
Staff gages clean (yes or no)		yes	yes	yes	yes	yes		yes
Picket leads clean (yes or no)		yes	yes	yes	yes	yes		yes
South Powerhouse Entrance:								
Depth over entrance weir								
SPE-1 (Criteria = 8 ft or >)	ft	7.5	9.7	7.2	7.1	6.5		7.6
SPE-2 (Criteria = 8 ft or >)	ft	7.5	9.7	7.2	7.1	6.5		7.6
Head at SPE-1 & 2 (Crit. = 1-2 ft)	ft	1.3	1.1	1.3	1.4	0.9		1.2
Gate on Sill (Yes or No)		yes	yes	yes	yes	yes		yes
Staff gages clean/readable (yes or no)		yes	yes	yes	yes	yes		yes
SOUTH SHORE FISHWAY								
South Shore Entrance:								
Depth over entrance weir								
SSE-1 (Criteria = 8 ft or >)	ft	8.3	8.3	7.9	8.0	7.9		8.4
SSE-2 (permanent) 6-feet	ft	6.0	6.0	6.0	6.0	6.0		6.0
Head at SSE-1 & 2 (Crit. = 1-2 ft)	ft	1.5	1.5	1.1	1.5	1.6		1.8
Gate on Sill (yes or no)		yes	no	yes	yes	yes		yes
Dep. over ladr. weir (Crit. = 1-1.3')	ft	1.1	0.9	1.1	1.1	1.0		1.0
Ladder exit clean		yes	yes	yes	yes	yes		yes
Picket leads clean		yes	yes	yes	yes	yes		yes
Pump speed	rpm	74	73	74	74	74		72-74
# of Pumps Operating (3 available)		3	3	3	3	3		3
Comment Number (if applicable)		1		2			3	4

Comments:

1. Channel orifice gates closed for season; water velocity estimated for channel as meter OOS.
2. Spare plastic backboard for the S Shore count station was floating between the picketed leads.
3. Scheduled inspection not completed due to 9/11/01 terrorist attacks and difficulties w/project access at Gov't facilities.
4. Lots of floating debris above the N.Shore fway exit--the air bubbler did not appear to work.

South Shore Fishway
Two south shore entrances are operated (both downstream, no side entrance) to attract fish to the spillway or south fish ladder. All auxiliary water is supplied from the north shore turbine driven pumps except for the 80 cfs flow that enters from the fish ladder. Gate SSE-2 is a fixed-open gate that remains 6-ft open while Gate SSE-1 is to be submerged 8 ft or more during normal operation. Gate depths at SSE-1 ranged from 7.9 ft to 8.4 ft, with the gate on sill during 5 of 6 inspections completed this season. The head differentials at the south entrances ranged from 1.1 ft to 1.8 ft and were within acceptable criteria for the season.

Fish Ladder: The south shore exit and the picketed lead section at the fish counting station was reported clear of debris this season. The depth of water over the ladder weirs ranged from 0.9 ft to 1.1 ft; the readings were acceptable although the May inspection was slightly less than the 1.0 ft desired.

Overall, fishways at the project were found operating within acceptable criteria for the 2001 inspection season with minor problems noted. The computer-controlled fishway appeared to perform very well and readings from the computer were normally close to the site readings obtained by the inspector. Some concerns are listed below.

- In past years, the turbine pumps at Lower Monumental Dam were susceptible to debris lodging in the wicket gates and other areas in the pumps. The trashrack section of the pumps should better exclude debris or else be self-cleaning or easily cleaned manually. This would make the auxiliary water supply more reliable during periods of high debris flow in the Snake River. The District should budget to include modifications to this critical passage element.

LITTLE GOOSE DAM (see photos page 51)

Little Goose Dam was completed in fall 1970 and is operated by the COE. The project consists of six main turbine units and eight spillbays of which six are equipped with fliplips.

The adult fish facilities incorporate six main entrance gates located at the south shore, north powerhouse, and north shore. Fish entering the north shore entrances are directed to the north end of the powerhouse, across the powerhouse collection channel, and then to the one fish ladder passing the project at the south end of the dam. Three turbine-driven pumps supply auxiliary water to the fishway and, with an additional 200 cfs excess flow from the juvenile bypass system; the adult fish facilities can normally operate within acceptable criteria throughout varying flow conditions.

Josh Hanson, ODFW, completed seven inspections of the Little Goose Dam fish facilities, commencing May 2 and ending October 19. Details of the inspections are given below and summarized in Table 7.

During 2001, the pumps operated with rpm levels ranging between 71 and 75 rpm. There were no reports that debris caused problems with operation of the pumps, i.e., reduced rpm from any pump this season.

Table 7. Pertinent Data for Fish Facility Inspections in 2001 at LITTLE GOOSE DAM.

CRITERIA ITEMS		DATE OF INSPECTION						
SOUTH SHORE FISHWAY		**2-May**	**16-May**	**27-Jun**	**18-Jul**	**24-Aug**	**21-Sep**	**19-Oct**
South Shore Entrance:								
Depth over entrance weir								
SSE-1 (Criteria = 8 ft or >)	ft	8.7	10.6	8.4	9.4	8.3	10.3	8.1
SSE-2 (Criteria = 8 ft or >)	ft	9.1	9.2	8.9	9.4	8.3	9.3	6.4
Head at SSE-1 & 2 (Criteria = 1-2 ft)	ft	2.0	1.6	2.0	1.7	2.1	1.7	1.8
Dep. over ladr. weir (Crit. = 1-1.3 ft)	ft	1.1	1.1	1.1	1.1	1.1	1.2	1.1
Channel velocity (Criteria = 1.5-4 fps)	fps	1.0	1.0	1.2	1.0	0.9	0.9	1.0
Channel velocity (North Shore)	fps	2.5	1.7	2.2	1.9	2.9	1.7	1.8
Ladder exit clean (yes or no)		yes	yes	yes	yes	yes	yes	yes
Staff gages clean (yes or no)		no	yes	yes	yes	no	yes	yes
Picket leads clean (Criteria = 0.3' max)		yes	yes	yes	yes	yes	yes	yes
North Powerhouse Entrance:								
Depth over entrance weir								
NPE-1 (Criteria = 7 ft or >)	ft	7.5	7.9	5.2	6.2	5.2	7.4	8.0
NPE-2 (Criteria = 7 ft or >)	ft	7.4	7.8	5.0	6.0	5.1	6.2	6.3
Head at NPE-1 & 2 (Criteria = 1-2 ft)	ft	1.6	1.5	2.0	1.6	1.8	1.4	1.6
Gate on Sill (Yes or No)		yes	yes	yes	yes	yes	1of 2	1of 2
Staff gages clean		no	yes	yes	no	no	yes	yes
Pump speed	rpm	72-75	71-74	73-75	73-75	73-75	73-75	74-75
Pumps Operating (3 available)		3	3	3	3	3	3	3
North Shore Entrance:								
Depth over entrance weir								
NSE-1 (Criteria = 6 ft or >)	ft	6.3	6.0	6.1	6.3	6.0	5.7	5.5
NSE-2 (Criteria = 6 ft or >)	ft	6.3	6.0	6.1	6.3	6.1	5.7	5.5
Head at NSE-1 & 2 (Criteria = 1-2 ft)	ft	1.3	1.2	1.6	1.0	1.8	1.5	1.6
Staff gages clean		yes	yes	yes	no	no	yes	yes
Comment number (if applicable)		1		2		3	4	5

Comments:

1. Several staff gages were unreadable; floating orifice gates closed for season; s shore equipment reads for gate depth require calibration.
2. NSE channel light is off or burned out since 6/11/01.
3. Staff gages were not clean; project was asked to check set point of SSEs for gate depth.
4. Project needs to check calibration of North Shore Channel and Tailwater gages (staff versus PLC).
5. Same comment as above. Gages read 0.6 ft apart and need calibration;

Project could have met gate depth criteria at the South Shore and NPEs.

Fishway Inspections

The two South Shore entrance Gates, SSE-1 and SSE-2, are operated to achieve an 8.0 feet or more weir submergence, with a head differential between 1.0 ft to 2.0. The project normally operated the south shore entrances to achieve 9.0 ft or more submergence depending on the tailwater elevation. Throughout the inspection season, the gate depths ranged from 6.4 ft to 10.6 ft, with head differentials ranging from 1.6 ft to 2.1 ft. Head readings were above the minimum of 1.0 ft all season. The gate depth on the final inspection was well below the criteria minimum of 8.0 ft with others satisfactory. Further, the gate settings did not appear to match adjacent gates with the SSE-1 set at 8.1 ft and the SSE-2 at 6.4 ft. In September, the gate depths were a foot different.

The two north powerhouse entrances, NPE-1 and NPE-2, were operated to meet the depth criteria of 7.0 ft or more submergence below tailwater. Through the inspections, the depths ranged from 5.0 ft to 8.0 ft. The NPE gates were on sill for the season with exception of the final two inspections. The head differential ranged from 1.4 to 2.0 ft for the season. With the gates on sill, and the "head" greater than 1.0 ft, the gates were normally operated at acceptable criteria. The NPEs were found operating with one gate on sill and the other 0.8 ft to 1.7 ft shallower on the final 2 inspections, similar to the SSEs. It appeared that the project could have easily met gate depth criteria during the final 2 inspections.

The velocity through the collection channel and to the north shore was recorded from 0.9 to 1.2 fps on the south end of the channel (electronic meter) and increased to >2.0 fps average at the northern end of the powerhouse channel. At the north shore entrance transport channel, a visual measurement of the surface velocity (floating chunk of wood) ranged from 1.7 to 2.9 fps.

In 2001, the orifice gates along the collection channel remained sealed; radio telemetry studies could find no significant differences of passage timing or delays by closing these gates. These gates will remain closed at the project.

The North Shore entrances were set to operate at 6.0 ft or more depth below tailwater, with the head differential in the range of 1.0 ft to 2.0 ft. Gate depths at NSE-1 and NSE-2 ranged from 5.5 ft to 6.3 ft for the season, with head differentials ranging from 1.0 ft to 1.8 ft. The head differentials were satisfactory during the inspections. The project could have met the 6.0 ft minimum criteria on all inspections based on head differentials recorded at the entrances during the final two inspections.

Fish Ladder: The fish ladder is located on the southern end of the dam with the exit from the ladder located between Unit 1 and the navigation lock. The fish ladder exit and the picketed leads at the count station were clear of debris throughout the 2001 season. The depth of water over the fish ladder weirs ranged from 1.1 to 1.2 ft for the season and readings were within an acceptable range.

Overall, the project operated the main fishway entrances close to acceptable limits during the 2001 fish passage season. Areas that should be improved follow:

- The staff gages should be replaced where necessary and **calibrated** so that readings can be compared between the computer and the on-site record, or a stillwell should be placed to measure tailwater elevation at the north shore. The staff gages required cleaning on two of the seven inspections.
- Currently, all weir depth readings are taken from the panel board in the powerhouse. An on-site comparison would be helpful to assure the computer settings are correct.
- **2001 was the first year that this project operated the main SSE and NPE gate settings at different elevations, e.g., the gate settings of SSE-1 and SSE-2 varied from 0.4 ft to 1.7 ft between individual gates on 5 of 7 inspections while NPE-1 and NPE-2 varied 1.2 ft and 1.7 ft between individual gates on the Sep/Oct inspections. Normally the individual gates are the same or within 0.1 ft of the adjacent gate settings related to depth below tailwater elevation.**

- Lights in the spillway channel were burned out on the N end of the spillway and the project repaired/replaced them during the season. Radio telemetry work showed few fish were using the tunnel during the low flow, no spill period.

LOWER GRANITE DAM (see photos page 52)

Lower Granite Dam was the last of the lower Snake River projects constructed by the COE; the project began operation in 1975. The powerhouse consists of six main turbine units and eight spillbays that are equipped with fliplips.

Three electric fish pumps supply water to the fishway; however, only two pumps can be operated at one time. Attraction flows are directed to two south shore entrances, two north powerhouse entrances, four operating orifice gates along the powerhouse collection channel, and two north shore entrances. No excess juvenile bypass water is incorporated into the adult attraction flow system at Lower Granite as occurs at the other three Snake River projects.

Josh Hanson, ODFW completed seven fishway inspections at Lower Granite Dam during 2001. Details of the inspections can be found in Table 8 and the text that follows.

Fishway Inspections

The South Shore fishway entrances, SSE-1 and SSE-2, operated with gate depths that ranged from 7.7 ft to 8.2 ft and head differentials that ranged from 1.6 ft to 1.9 ft. Normally, the gate depths were near 8.0 ft submerged below tailwater elevation with the head differential averaging 1.7 ft. Based on inspection results, there was sufficient head differential to allow for deeper submergence of these gates throughout the fish passage season.

Water velocity was recorded via an electronic meter at the southern end of the collection channel. For the season, the water velocities ranged between 0.9 fps to 1.1 fps. The velocity meter is located at the start of the collection channel and in the slowest part of the channel. This is an area that should be further evaluated based on fish behavior at the transition into the junction pool and turn pool. Water velocity is also recorded at the North Shore channel and velocities ranged from 1.8 fps to 2.9 fps.

The North Powerhouse entrances, NPE-1 and NPE-2, were operated with the Gates on sill for six of seven inspections. A gate depth of 8.1 ft average was reached on the October inspection. Gate depths for the season ranged from 5.3 ft to 8.2 ft. Head differentials ranged from 1.1 ft to 1.4 ft for the season. All inspections showed the NPE gates operating satisfactorily and within criteria (given the water elevations) during this season's fishway inspections.

All tailwater elevations from the north shore were again taken from the FSC Board as the tailwater staff gage was not re-installed during the 2001 winter maintenance season. This year's inspections showed North Shore entrances, NSE-1 and NSE-2, had gate depths ranging from 5.0 ft to 7.3 ft and head differentials that ranged from 0.8 ft to 1.1 ft. To the extent possible, the project maintains a minimum head differential of 1.0 ft, while allowing the gate depth to adjust to meet the head differential criteria.

Fish Ladder: Adult fish exit the fish ladder at the south shore of the project. The ladder exit and picketed leads (count station) were reported clear of debris on all inspections during the fish passage season. The depth of water over the fish ladder weirs ranged between 1.1 ft and 1.2 ft.

Overall, the adult fish facilities operated with few mechanical problems in 2001 relating to pumps or entrance gates. Several limitations of the fish facilities still exist.

- The project has three fish pumps, but only two can be operated due to hydraulic limitations of the system. As a result, the north shore entrance gates cannot operate to meet both gate depth and head differential criteria under most conditions, even through the gates could be lowered further in the gate slot.
- **The project should reinstall the broken staff gage(s) at the north shore. There has been no way to obtain a reliable tailwater elevation reading for several years. Another alternative would be to install a stillwell to allow a tailwater reading. It has been nearly impossible to tell whether the north shore is calibrated correctly.**
- Water velocity through the beginning of the southern end of the powerhouse collection channel was less than or close to the minimum criteria desired for most of the fish passage season. A review of the radio telemetry study relating to fish passage through this section of the channel would be helpful in determining what effect this might have on adult fish.
- **Based on initial radio telemetry study results, it appeared that only one of the two South Shore entrance gates was resulting in net passage of adult fish. Potentially, closing the downstream gate would allow the other SSE gate to operate at a deeper depth and attract additional fish to the one gate.**
- **Also, it should be determined whether closing orifice gates along the powerhouse collection channel might increase Q to the North Shore Entrances.**

Table 8. Pertinent Data for Fish Facility Inspections in 2001 at LOWER GRANITE DAM.

CRITERIA ITEMS		DATE OF INSPECTION						
		3-May	17-May	26-Jun	18-Jul	14-Aug	19-Sep	19-Oct
SOUTH SHORE FISHWAY								
South Shore Entrance								
Depth over entrance weirs								
SSE-1 (Criteria = 8 ft or >)	ft	7.8	8.1	8.0	8.1	8.1	7.7	7.7
SSE-2 (Criteria = 8 ft or >)	ft	7.8	8.1	7.9	8.1	8.1	7.8	8.2
Head at SSE-1 & 2 (Crit. = 1 - 2 ft)	ft	1.8	1.9	1.6	1.6	1.6	1.9	1.6
Depth over ladr. Weir (Crit.= 1-1.3 f	ft	1.1	1.1	1.1	1.1	1.1	1.2	1.2
Channel velocity (Crit. = 1.5-4 fps)	fps	1.0	0.9	0.9	1.1	0.9	0.9	0.9
Channel velocity (n shore)		2.0	2.1	2.9	2.4	2.5	2.2	1.8
Ladder exit clean (yes or no)		yes	yes	yes	yes	yes	yes	yes
Staff gauge clean (yes or no)		yes	yes	no	yes	yes	yes	yes
Picket leads clean (yes or no)		yes	yes	yes	yes	yes	yes	yes
North Powerhouse Entrance:								
Depth over entrance weir								
NPE-1 (Criteria = 8 ft or >)		6.2	7.7	5.5	5.4	5.6	5.4	8.2
NPE-2 (Criteria = 8 ft or >)		6.2	7.5	5.5	5.3	5.5	5.3	8.0
Gate on sill (Yes or No)		yes	yes	yes	yes	yes	yes	no
Head at NPE-1&2 (Criteria = 1-2 ft)		1.4	1.2	1.1	1.3	1.4	1.4	1.2
Staff Gauge clean		yes	yes	yes	yes	yes	yes	yes
North Shore Entrance:								
Depth over entrance weir								
NSE-1 (Criteria = 7 ft or >)		6.1	7.2	6.2	6.1	5.9	5.6	5.0
NSE-2 (Criteria = 7 ft or >)		6.1	7.3	6.1	6.1	5.9	5.6	5.0
Head at NSE-1&2 (Criteria = 1-2 ft)		0.9	1.1	1.0	0.8	0.9	1.2	1.1
Staff Gauge clean	TW staff gage broken for season							
Comment number (if applicable)		1	2		3	4	5	6

Comments:

1. The n shore tailwater staff gage was not replaced in 2001 (broken since 1996 flood).
2. S Shore surface velocity remains below 1.5 fps.
3. NSE channel staff gage reads consistently 0.2' off from the FSC board; requires calibration.
4. NSE head differential less than 1.0 ft and gate depths below 7.0 ft; Lights burned out on N end of powerhouse spillway; Water velocity still very low at the S end of the powerhouse collection channel.
5. Project still operating at reduced gate depths for the summer season.
6. NSE channel staff gage and FSC reading off by 0.7 ft; NPE lights appear out; weir depths OOC at SSE & NSE.

PUBLIC UTILITY DISTRICT PROJECTS

The Public Utility District Projects comprise 5 mainstem Columbia River dams from Priest Rapids Dam located above the free-flowing Hanford Reach section of the Columbia River to Wells Dam located about 45 miles upstream from Wenatchee, WA. Grant County PUD owns and operates the lower two dams, Priest Rapids and Wanapum dams; Chelan County PUD – Rock Island and Rocky Reach dams; and Douglas County PUD – Wells Dam. These dams use a variety of pump systems or gravity-flow water to supply AWS channels that feed this water through diffusion systems into the main collection chambers. In 2001, Grant PUD projects used orifice gates along their powerhouse collection channels to late July and then closed them during the latter part of the adult migration season. In 2002 and in future years, these orifice gates will be closed and adult fish will be attracted and passed only through the main entrance gates. Rocky Reach will be the only project to use orifice gates along its powerhouse in 2002. Wells and Rock Island dams do not have orifice gates along their powerhouses; only main entrance gates located at either end of the powerhouse channels are used to attract fish to the ladder area.

Prior to the 2001 fish passage season, fish agency and tribal personnel met with the PUD staff to discuss inspections from the previous season (2000) and to review modifications that were made at adult or juvenile fish facilities at the five Mid-Columbia dams. These meetings have provided excellent opportunity to discuss and assess adult fish facility and passage conditions at the PUD projects. Presently, fishway inspections report operation of adult fish facilities at the individual PUD projects with spill levels and patterns recorded.

PRIEST RAPIDS DAM (see photos page 53)

Priest Rapids Dam construction was completed in 1959. The hydropower plant contains ten main turbine units and 22 spillbays. The project is owned and operated by Grant County (PUD). The adult fish facilities consist of two fishways, one located on the left bank and the other on the right bank of the Columbia River. Makeup water for the lower end of the fish ladder is stored in an Auxiliary Water Supply (AWS) pool located on the left bank of the project. The AWS pool is filled by five electric pumps that pull water from the tailrace and a Gravity Intake Gate (GIG) that pulls water from the forebay of the project. AWS pool water is channeled through a diffusion system (mostly floor diffusers) into the collection channel and lower end of the fish ladder at both shores of the project.

Main entrance gates on the Left Bank fishway are located at the eastern end (shore entrance) and the western end of the powerhouse. Nine of eighteen orifice gates operate along the powerhouse collection channel. One main entrance gate is operated at the Right Bank fishway. All main entrance gates are slotted gates and rely on maintaining a head differential of 1.0 to 2.0 feet to be in criteria range.

Melissa Jundt, NMFS completed 7 inspections of the adult fish facilities during the 2001 season beginning April 17 and ending October 17 (Table 9). An operator and a fish biologist or tech from Grant Co. PUD normally accompanied Melissa during the inspection. Priest Rapids Dam fishways are computer controlled and computer printouts identifying set points and actual readings can be generated as needed. The computer-generated readings are normally compared to the site readings to assess whether calibration of the equipment was necessary, or if tailwater elevations or project operations were changed during the inspection.

Left Bank Fishway

At the West end of the powerhouse, Gate LSE-2 operated throughout the fish migration season. During 2001, head differentials ranged from 1.0 ft to 1.6 ft. The project was operating within acceptable criteria (1.0 ft to 2.0 ft) on all seven inspections, with the targeted head of 1.2 ft met or exceeded on four of the seven inspections.

Gate LSE-4 is located on the East end of the powerhouse and operated throughout the fish migration season. During 2001, head differentials were within criteria of 1.0 ft to 2.0 ft on all inspections and ranged from 1.0 ft to 1.3 ft. However, the targeted head differential of 1.5 ft for Gate LSE-4 was not achieved on any inspection, same as the previous season.

Water velocity in the collection channel was visually estimated and ranged between a low of near 2.0 fps to a high estimate of 2.8 fps. This season's readings marked the first time all readings exceeded the minimum readings of 1.5 fps. Water velocities in the channel appeared far superior in 2001 compared to previous years when the fishway channgel was operated with the orifice gates open for the season.

Fish Ladder: At the Left Bank fish ladder, the depth of water over the ladder weirs ranged between 1.0 ft and 1.3 ft for the season; all satisfactory readings. The exit from the fish ladder was clear of debris for the season. The picketed leads at the counting station were not reported for the season as having debris or passage problems.

Right Bank Fishway

Auxiliary water from the Left Bank is transported via a large conduit to the Right Fishway. This water flows through diffuser gratings into the lower end of the right bank fish ladder. Slotted Entrance Weir, RSE-1, operated during the 2001 fish passage season. The main gate is required to operate within the following range: 1.0 to 2.0 ft for head differential with the target "head" being 1.5 ft. Gate RSE-1 had head differentials ranging from 1.1 to 1.3 ft for the season. All readings were within the operating criteria, with the target "head" of 1.5 ft not achieved on any inspection during 2001.

Fish Ladder: The depth of water reported over the fish ladder weirs was 1.0 ft on 6 of 7 inspections with the initial inspection showing a 1.1 ft depth. The ladder exit was reported clear of debris on all inspections this season.

Overall, the adult fish passage facilities were operated within criteria range for head differential throughout the season. The greatest area of improvement this season was the increased water velocity through the powerhouse collection channel. The orifice gates along the powerhouse were again evaluated for adult fish passage and delays. None were readily observed from the radio telemetry study so the orifice gates will not be operated in future years at Priest Rapids Dam. Potential areas of concern relating to project operation are listed:

- Fluctuations of flow affecting tailwater elevations resulted in staff gages being nearly impossible to read. Computer readings were used at several locations because of staff gages being unreadable.
- Entrance RSE-1 and LSE-4 did not meet the target head of 1.5 feet on any inspection during 2001; LSE-2 met the target head of 1.2 feet on 4 of 7 inspections. The project should set target head differentials on the computer system and maintain these differentials where possible.
- The adult fish-trapping site located in the left bank fish ladder will slow passage of fish when it is operated. It would be better if the trap were changed to an off-ladder trapping system similar to the Bonneville trap site. Although any trapping site will affect passage of fish, an off-ladder trap provides less passage or delay problems than in-ladder traps. **The trapping braille and other parts of the trap should be upgraded during the 2002 winter maintenance period.**
- The fish trap that was originally used by WDFW to aid in brood stock collection at Priest Rapids Hatchery has not been used for greater than 10-years and should be removed if approval can be obtained from WDFW or other agencies.

Table 9. Pertinent Data for Fish Facility Inspections in 2001 at PRIEST RAPIDS DAM.

CRITERIA ITEMS		DATE OF INSPECTION						
LEFT BANK FISHWAY		17-Apr	6-Jun	28-Jun	24-Jul	29-Aug	27-Sep	17-Oct
Left Bank Entrance:								
Head at main entrances (Criteria = 1-2 ft)								
LSE-2 (1.2 ft target)	ft	1.2	1.0	1.1	1.7	1.2	1.6	1.0
LSE-4 (1.5 ft target)	ft	1.3	1.2	1.3	1.2	1.1	1.3	1.0
Depth over ladr. weir (Crit. = 1-1.2 ft)	ft	1.3	1.0	1.1	1.0	1.2	1.0	1.0
Water velocity (Crit. = 1.5-4 fps)	fps	2.0	2.0	2.0	2.5	2.0	2.8	2.0
Ladder exit clean (Crit. = yes or no)		yes	yes	yes	yes	yes	yes	yes
Staff gages clean (Crit. = yes or no)		yes	yes	yes	no	yes	no	no
Picket leads clean (Crit. = yes or no)		yes	yes	yes	yes	yes	yes	yes
RIGHT BANK FISHWAY								
Right Bank Entrance:								
Head at Entrance (Criteria = 1-2 ft)								
RSE-1 (1.5 ft target)	ft	1.2	1.0	1.0	1.0	1.1	1.0	1.1
Depth over ladr. weir (Crit. = 1-1.2 ft)	ft	1.1	1.0	1.0	1.0	1.0	1.0	1.0
Ladder exit clean (Crit. = yes or no)		yes	yes	yes	yes	yes	yes	yes
Staff gages clean (Crit. = yes or no)		yes	yes	yes	no	yes	yes	yes
Picket leads clean (Crit. = yes or no)		yes	yes	yes	yes	yes	yes	yes
Comment number (if applicable)					1			2

Comments:

1. Channel orifice gates closed on July 13 as part of the steelhead and lamprey migration study.
WDFW sampling adult fish at the L. Bank fish ladder trap.
2. The project needs to repair the trap brail to assure it is operable prior to the next trapping season.

WANAPUM DAM (see photos page 54)

Wanapum Dam hydro project was completed in 1963 with ten main turbine units for power production and 12 spill gates to pass excess flow. The project is owned and operated by Grant County PUD. Two turbine-operated pumps that pull water from the tailwater of the dam and are driven by gravity flow water from the forebay of the dam, supply makeup water to the Left Bank Auxiliary Water Supply (AWS) pool. Two 10-foot diameter butterfly valves (forebay gravity water) provide a backup system for the turbine driven pumps. Fishway water flows through the two main slotted fishway entrances, LSE-2 at the eastern end of the powerhouse (shore), and LSE-3 at the western end of the powerhouse. This same water supply also feeds ten operating orifice gates along the powerhouse collection channel. Orifice gates along the channel were closed on 7/13 as part of a steelhead and lamprey migration study.

Auxiliary water for the Right Bank fishway is a gravity flow system that pulls water from the forebay of the dam. This water normally supplies sufficient Q to the diffusers located in the lower end of the fish ladder to meet head differential criteria established for main entrance gate, RSE-2.

Melissa Jundt, NMFS, completed seven fishway inspections beginning April 17 and ending October 17. A summary of the inspections is listed in Table 10 and in the text below.

Left Bank Fishway

The east slotted entrance LSE-2 operates as the primary entrance weir with a head differential criterion of 1.0 ft to 2.0 ft and a target of 1.5 ft. Gate LSE-2 operated within the following range: 1.2 ft to 2.1 ft and was within acceptable range the entire season (0.1 ft high in the July inspection). The project maintained or was within 0.1 ft of the targeted head of 1.5 ft on 6 of the 7 inspections.

The west slotted entrance, LSE-3, is the primary entrance weir with an operational criterion of 1.0 ft to 2.0 ft and targeted head differential of 1.25 ft. Gate LSE-3 operated within the following range: 1.2 ft to 1.6 ft for the fish passage season. The target of 1.25 ft was met on all seven inspections (1.2 ft was considered satisfactory).

Water velocity was estimated along the channel and readings ranged between 2.0 and 2.8 fps. All readings exceeded the minimum criteria of 1.5 fps during the 2001 inspection season. Orifice gates along the channel were closed from the July inspection through the end of the season and may have contributed to improved water velocity readings recorded this season. On all other inspections, the orifice gates were operating satisfactorily and in proper sequence.

Fish Ladder: The depth of water over the fish ladder weirs ranged from 0.9 ft to 1.2 ft for the season and was below 1.0 ft minimum reading (0.1 ft low only) on two of the 7 inspections. The ladder exit was considered clear of floating debris around the exit on six of the seven inspections.

Right Bank Fishway

The right bank slotted entrance weir, RSE-2, is targeted to operate with a head differential of 1.25 ft and within the range of 1.0 ft to 2.0 ft. Gate RSE-2 is the primary entrance weir and operated with head differentials ranging from 1.0 ft to 1.5 ft. All inspections met the minimum criterion of 1.0 ft for the season, with the targeted head differential met 6 of the 7 inspections during 2001.

Table10. Pertinent Data for Fish Facility Inspections in 2001 at WANAPUM DAM.

CRITERIA		DATE OF INSPECTION						
LEFT BANK FISHWAY								
Left Bank Entrance:		**17-Apr**	**6-Jun**	**28-Jun**	**24-Jul**	**29-Aug**	**27-Sep**	**17-Oct**
Head at entrances (Criteria = 1-2 ft)								
LSE-2 (target head = 1.5 ft)	ft	1.4	1.9	1.4	2.1	1.9	1.8	1.2
LSE-3 (target head = 1.25 ft)	ft	1.2	1.3	1.5	1.5	1.6	1.4	1.2
Dep. over ladr. weir (Crit. = 1.0-1.2ft)	ft	1.1	0.9	1.1	1.1	1.2	1.2	0.9
Channel velocity (Crit. = 1.5-4.0 fps)	fps	2.5	2.0	2.0	2.5	2.5	2.3	2.8
Staff gages clean (Crit. = yes or no)		yes	yes	yes	no	yes	yes	yes
Auxiliary H20 Pumps	rpm	170/175	160/165	135/140	130/150	135/145	130/140	140/150
Ladder exit clean (Crit. = yes or no)		yes	yes	yes	yes	fair	yes	yes
RIGHT BANK FISHWAY								
Right Bank Entrance:								
Head at Entrance (Criteria = 1-2 ft)								
RSE-2 (target head = 1.25 ft)	ft	1.2	1.2	1.0	1.4	1.4	1.5	1.5
Depth over ladder weir	ft	1.0	0.9	1.2	1.2	1.2	1.1	1.1
Ladder exit clean		yes	yes	yes	yes	yes	yes	yes
Staff gages clean		yes	no	no	yes	yes	yes	no
Comment number (if applicable)		1			2			3

Comments:

1. Gravity Regulating Valve open, but indicator not working to give % open.
2. Channel orifice gates closed on 7/13 as part of a steelhead and lamprey migration study.
3. Reverse Load factoring with forebay drawn down about 6.0 ft.

Fish Ladder: The right fish ladder operated with depth of water over the weir crests ranging between 0.9 ft and 1.2 ft for the season. The 0.9 ft reading was 0.1 ft lower than recommended. The fish ladder exits were reported clear of debris for the 2001 season.

Spill Patterns: Spill for juvenile fish was used to pass fish downstream of the project (April – August). Changes to the spill schedule were coordinated through the fish agencies and tribes.

Overall, the Wanapum fish facilities operated satisfactorily throughout the fish passage season with few exceptions. Some problem areas are listed below:

- As tailwater elevations drop during the summer/fall, many of the staff gages become unreadable. Either removable staff gages should be installed or bench markers placed that would allow use of a sensor tape to obtain accurate elevation readings for the main entrances. Same comment as in 2000.
- During 1998-2001, the District tested a video camera system to assess passage of adult fish through selected orifices in the upper section of the fish ladders at the project. Based on the large discrepancies noted in fish counts between Priest Rapids Dam and Rock Island Dam in 1999 and 2000, it would be very beneficial to have accurate fish counting at Wanapum Dam.
- The project should complete computerized automation of the adult fishway facilities. This was initiated several years ago but never completed.

ROCK ISLAND DAM (see photos page 55)

The Rock Island hydro-project is comprised of two powerhouses; an old powerhouse with 10 main turbine units that was constructed in 1933, with a major upgrade of the turbine units in 1953. A new powerhouse with eight main turbine units and located on the right bank of the Columbia River was completed in 1979. The spillway, consisting of 31 spillbays (numbered 1-32 exclusive of 15, which is now the Middle Fishway), is located between the two powerhouses. The dam is owned and operated by Chelan County PUD.

The old powerhouse adult fish facilities consist of the Left Bank fishway and the Middle or Spillway fishway, while the new powerhouse has the Right Bank fishway. Each fishway has a fish counting station located near the top of the fish ladder.

Denise McCarver, Glen Liner, and Steve Gacek, WDFW completed 7 inspections of the adult fish facilities at Rock Island Dam during the 2001 fish passage season beginning April 24 and ending October 17 (Table 11).

Left Bank Fishway

Gravity-fed water is supplied from the forebay to the lower end of the Left Bank fish ladder through diffuser gratings. This auxiliary water supplies sufficient flow to allow Gates LO5 and LO6 to operate at 6.0 ft or greater depth with a corresponding head differential of 1.0 ft minimum through all tailwater elevations.

Gates LO5 and LO6 were normally submerged the same depth or within a tenth of the other gate during the 2001 season with the gate depths ranging from 6.5 ft to 7.0 ft. Head differentials ranged between 1.0 ft and 1.3 ft. The gate depth and head differential readings were found within acceptable criteria range through the inspection season. The exception in 2001 occurred during the July inspection when Gate LO5 was broken and was on sill. This resulted in the Gate being submerged 10.1 ft with Gate LO6 submerged 6.6 ft. The reading was satisfactory. Project personnel repaired Gate LO5 by August 1.

Fish Ladder: Depth of water measured over the Left Bank fish ladder weirs was 1.1 ft during the passage season. During the 23 May inspection, we found one dead adult spring chinook that had jumped out of the left fish ladder. We recommended that a net be placed over the ladder and the project was able to do so

before the end of the fish run. The exit trash racks located at the exit from the fish ladder and the picketed leads at the counting station were clear of debris during the inspections. The project reported increased amounts of floating grasses in the river this season.

Middle Fishway

Gravity feed water from the forebay of the dam supplies water to the lower end of the fish ladder through floor diffusers. The end gate and a fixed-open side gate operate to attract adult fish from the spillway section of the dam. The end gate, MO3, is required to operate at 8.5 ft or greater depth below tailwater, while the side gate is continually open and depends on head differential to be within acceptable criteria. The head differential required for both gates is the standard 1.0-ft to 2.0-ft range. See Recommendation Section regarding diffuser gratings.

Gate depths recorded during the inspections ranged from 7.4 ft to 8.9 ft. The head differentials during the season ranged from 1.1 ft to 1.6 ft. The MO3 Gate was on sill during the October 17 inspection so no further depths could be attained; however, head differential was 1.6 ft and flow should have provided satisfactory passage for adult fish at the middle ladder during the inspection.

Fish Ladder: The depth of water over the fish ladder weirs was reported at 1.1 ft for all seven inspections. The picketed leads and the ladder exit were clear of debris during the inspections.

Spillway: Specific spillbays at the project have been modified (notched) to improve passage for juvenile salmonids. Bays affected for the year were 1, 16, 18, 24 through 26, and 29 through 32. Approximately 20 kcfs of the river flow was utilized for fish spill during the April and May inspections through these gates. No spill was used during the 2001 summer. Adult fish passage through the middle ladder was not compromised due to the spill or spill pattern based on fish counts at the middle ladder.

Right Bank Fishway

Auxiliary water is supplied to the Right Bank Fishway from three fish pumps that pull water from the tailwater and gravity-fed water from the forebay of the dam. Most of this flow enters the fishway in the lower end of the fish ladder through sidewall diffusers. The attraction water is distributed to an entrance gate at the downstream end of the project, one main gate at the left end of the powerhouse, and through two gates at the right end of the powerhouse. Each entrance gate is opened 3-ft, but its depth will increase as flow and tailwater elevation increases. The gates are operated to meet head differential criteria of 1.0 to 2.0 ft. In addition to the entrance flow, a high velocity flow of water is discharged below the water surface near the right powerhouse entrance gates. The purpose of this high velocity flow is to attract fish to the right powerhouse entrances from across the face of the dam. The pumped flow water was operated at 100% open on five inspections; the gravity-flow water was at 100% on all seven inspections.

The entrance gates, TPE, LPE, and the RPEs were reported with head differentials that ranged from 0.9 ft to 1.8 ft throughout the season. Head differential was less than 1.0 ft only at the TRE, 0.9 ft was recorded during the July inspection with all other entrances recording at least 1.0 ft head differential. When tailwater elevations exceed or are close to an elevation of 575.0 ft, the

Table 11. Pertinent Data for Fish Facility Inspections in 2001 at ROCK ISLAND DAM

CRITERIA ITEMS		DATE OF INSPECTION						
		24-Apr	23-May	25-Jun	25-Jul	27-Aug	26-Sep	17-Oct
LEFT BANK FISHWAY								
Left Bank Entrance:								
Depth over entrance weir								
LO5 (Crit. = 6.0 ft or >)	ft	6.8	6.9	6.5	10.1	6.7	7.0	7.0
LO6 (Crit. = 6.0 ft or >)	ft	6.8	6.9	6.5	6.6	6.7	7.0	7.0
Head at LO5 & 6 (Crit. = 1-2 ft)	ft	1.3	1.0	1.2	1.2	1.3	1.2	1.1
Dep. over ladr. weir (Cr. = 1-1.2')	ft	1.1	1.1	1.1	1.1	1.1	1.1	1.1
Staff gages clean (yes or no)		yes	yes	yes	yes	yes	yes	yes
Ladder exit clean (yes or no)		yes	yes	yes	yes	yes	yes	yes
Picket leads clean (yes or no)		yes	yes	yes	yes	yes	yes	yes
CENTER FISHWAY								
Center Entrance:								
Depth over entrance weir								
MO7 (Criteria = 8.5 ft or >)	ft	8.5	8.7	8.5	8.9	8.7	8.5	7.4
Head at MO7 (Criteria = 1-2 ft)	ft	1.1	1.3	1.2	1.3	1.3	1.4	1.6
Dep. over ladr. weir (Cr. = 1-1.2')	ft	1.1	1.1	1.1	1.1	1.1	1.1	1.1
Ladder exit clean (yes or no)		yes	yes	yes	yes	yes	yes	yes
Picket leads clean (yes or no)		yes	yes	yes	yes	yes	yes	yes
RIGHT BANK FISHWAY								
Right Bank Entrance:								
Head Differential (Crit. = 1-2 ft)								
LPE-1	ft	1.1	1.3	1.5	1.2	1.2	1.4	1.8
RPE-1 and RPE-2	ft	1.5	1.5	1.5	1.2	1.3	1.5	1.4
TRE	ft	1.1	1.2	1.2	0.9	1.1	1.3	1.2
Dep. over ladr. weir (Cr. = 1-1.2')	ft	1.1	1.1	1.1	1.1	1.1	1.1	1.1
Channel velocity (Cr. = 1.5-4 fps)	fps	4.3	4.4	4.3	4.7	4.6	4.4	4.4
Ladder exit clean (yes or no)		yes	yes	yes	yes	yes	yes	yes
Picket leads clean (yes or no)		yes	yes	yes	yes	yes	yes	yes
Pumps operating		3	3	3	3	3	3	3
Pump Gate Openings	%	40-100	100	100	98 ave	100	100	27-100
Comment number (if applicable)		1	2		3	4		5

Comments:

1. Juvenile Fish spill through selected gates; sampling boat docked about 50 yd from Left Entrance Gates.
2. Found dead adult spring chinook that had jumped out of L fish ladder; recommended a net placed over ladder.
3. No summer spill for juvenile passage; Gate LO5 broken - Repair by 8/1; Heavy grass on intakes.
4. Very heavy movement of grasses in the Columbia River in 2001.
5. Middle ladder gate on sill; no further depth could be attained.

head differentials drop below the minimum 1.0 ft; however, with the low runoff and stream flow in the Columbia River in 2001, this elevation was seldom exceeded. Water velocity recorded in the powerhouse transportation channel was measured using a flow meter. Velocity ranged between 4.3 to 4.7 fps during the inspections. These velocity readings are greater than the high criteria of 4.0 fps; however, adult fish readily pass through this channel section with little or no delay.

Fish Ladder: Depth of water measured over the ladder weirs was 1.1 ft for the Right ladder on each inspection and was within acceptable range of 1.0 to 1.2 ft. The exit from the fish ladder was clear of debris, as was the picketed lead section at the fish counting station.

Overall, the fish passage facilities operated within criteria limits for the 2001 adult fish passage season. Areas of concern are listed below.

- Adult fallback should be assessed, given the increased number of spillbay gates that are presently being used to pass juvenile fish at the project.
- The Right Bank Fishway cannot meet head differential criteria at the main entrances when tailwater elevations increase to near or above elevation 575.0 ft.
- In the Middle Fishway, begin video camera inspections of the diffuser gratings to assess their condition throughout the fish passage season.
- The differential between the supply pool and the side wall diffusers was excessive this season (greater than 1.0 ft noted) and the project should assess how to reduce amount of grasses and debris that build on these wall screens before they potentially collapse during the late summer or fall.

ROCKY REACH DAM (see photos page 56)

Rocky Reach Dam was completed in 1961 and is owned and operated by Chelan County PUD. The project is comprised of 11 main turbine units and 12 spillbays to pass water through the dam. Turbine Unit 11 is the only remaining fixed blade unit and is currently undergoing refurbishment. The project has been modifying the turbine blades and units to make them more “fish friendly” and should result in reduced mortality for juvenile or adult fish that pass through the turbines.

The adult fish facilities are comprised of three turbine-driven propeller-type fish pumps that supply water from the tailwater of the project for the powerhouse fishway entrances, most of the spillway entrance flow and the six orifice gates along the powerhouse collection channel. The fish pumps operated satisfactorily during the 2001 fish passage season. Additional gravity-flow water can be supplied at the main spillway entrance to maintain the agreed upon criteria for that entrance. The powerhouse collection, left powerhouse, and spillway channels merge in the junction pool area to form the transportation channel. The transportation channel guides fish to the lower end of the fish ladder. The fish ladder exit is located on the Right Bank of the Columbia River.

Denise McCarver, Glen Liner, and Steve Gacek, WDFW, inspected the adult fish passage facilities seven times during 2001 season with the initial inspection on April 24 and the final inspection on October 17. Normally, the fishways were operating close to acceptable criteria ranges with few exceptions. Table 12 lists inspections and pertinent data with the text filling in details of the activities for this season.

Powerhouse Entrances

The Right Powerhouse Entrances (RPE-1 and RPE-2) are rotary wing gates that operate with a 3-ft opening, and require head differential of 1.0 ft to 2.0 ft. In 2001, the head differential ranged between 1.0 to 1.1 ft during the inspections at the RPEs. Six orifice gates along the channel (1, 2, 3, 14, 16, and 20) operated satisfactorily this season.

The Left Powerhouse Entrances, LPE-1 and LPE-2, are located at the left end of the powerhouse nearest to Main Turbine #11. One entrance discharges its flow back toward the powerhouse with the other discharging its flow toward the retaining wall that separates the spillway flow from the powerhouse flow. The main powerhouse discharge is at right angle to the spillway discharge.

Gate depths at LPE-1 and LPE-2 ranged from 11.0 ft to 12.8 ft, with head differentials that ranged from 1.1 ft to 1.5 ft (very similar to 2000 inspection data). The gates were operating within criteria limits throughout the 2001 inspection season. The "head" was within the required ranged of 1.0 – 2.0 ft on all inspections.

This season, the water velocity in the transportation channel ranged from 1.7 to 1.9 fps and readings were within an acceptable range, i.e., 1.5 to 4.0 fps.

Main Turbine Unit #11 was operating on one of the seven inspections during the season. It is still unknown whether operation of this Unit affects passage of adult fish at the LPEs; however, the turbine boil does not allow the flow from the LPEs to extend, as far into the tailwater as when the Unit does not operate.

Spillway Entrance

The Spillway Entrance, MSE was not operated in 2001.

Fish Ladder: The exit from the fish ladder was clear of debris during the 2001 inspection season. The depth of water over the fish ladder weirs was 1.0 ft during all inspections and was within the criterion range of 1.0 and 1.2 ft.

Overall, the fishways were operating within criteria with few exceptions. The fishway attendants continued coverage of the fishways over a larger part of the day to assure that the fishways were kept closer to criteria levels during the early morning hours when flows were rapidly changing at the project. These efforts should result in better passage conditions throughout the adult fish migration season.

Table 12. Pertinent Data for Fish Facility Inspections in 2001 at ROCKY REACH DAM.

CRITERIA ITEMS		DATE OF INSPECTION						
		24-Apr	23-May	22-Jun	25-Jul	27-Aug	26-Sep	17-Oct
ADULT FISHWAY								
Left Powerhouse Entrance:								
Depth over entrance weirs								
LPE-1 & 3 (Depend. On Tw Elev)	ft	11.4	12.7	12.3	11.0	12.8	12.0	12.1
Head at LPE-1 & 3 (Crit. = 1-2 ft)	ft	1.2	1.1	1.2	1.5	1.3	1.4	1.3
Depth over Ladr Weir (Crit = 1-2 ft)	ft	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Channel velocity (Crit. = 1.5-4 fps)	fps	1.7	1.7	1.9	1.9	1.8	1.7	1.8
Ladder exit clean (yes or no)		yes	yes	yes	yes	yes	yes	yes
Picket leads clean (yes or no)		yes	yes	yes	yes	yes	yes	yes
Turbine 11 Operating (yes or no)		no	yes	no	no	no	no	no
Right Powerhouse Entrance:								
Wing gate opening (Criteria = 3.0 ft)								
RPE-1 and RPE-2	ft	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Head at RPE-1&2 (Crit. = 1-2 ft)	ft	1.0	1.0	1.0	1.0	1.0	1.0	1.1
Orif. Gates Oper - (1,2,3,14,16, 20)	y/n	yes	yes	yes	yes	yes	yes	yes
Pumps operating		3	3	3	3	3	3	3
Fish Pump Speed	rpm	40	43	51	47	47	47	50
Spillway Entrance:								
Depth over entrance weir								
MSE (Dependent on Tailwtr Elev.)	ft	Closed	Closed	Closed	Closed	Closed	Closed	Closed
Head at MSE (Criteria = 1-2 ft)	ft							
Comment number (if applicable)						1		

Comments:

1. Surface Collector has been in operation since April; grass cleaned from intake screens eve - 8/23.

WELLS DAM (see photos page 57)

Wells Dam was completed in 1967 with 10 main turbine units and the spillbays placed directly above them. The turbine units are termed hydrocombines. The hydropower project is owned and operated by Douglas County PUD.

The adult fish passage facilities were built and incorporated into the project during the construction phase. The West and East Bank fishway entrances are similar in design and in past years normally operated with an end gate and a side gate open. The end and side gates are wing gates and can open to 8-ft at maximum width. The depth of water passing through the entrance gates extends from the floor of the fishway to the water surface elevation in the entrance pool. In previous years, high velocity water discharge pipes normally operated near the side entrances at different elevations (depending on tailwater elevation) and water was discharged toward Unit 1 and Unit 10 to attract adult fish to the side entrances. These jets operated only when the side entrances were open. **In 2001, only the end gates were operated, and in addition, no high velocity water jets were operated.**

Stewart Mitchell, WDFW, completed seven inspections of the adult fishways during 2001. The initial inspection was May 1 with the final inspection on October 16. Results of the inspections are summarized in Table 13 with discussion relating to overall inspections for the year in the text below.

Water is supplied to the main entrances by two turbine-driven fish pumps (2 per side) that diffuse water into the lower end of the fish ladder through wall and floor diffuser gratings. The pumps operated satisfactorily throughout the 2001 fish passage season with no reported out of service time. The project can normally meet head differential criterion at the main entrances through all tailwater elevation fluctuations and flow conditions.

The West and East fish ladders incorporate trapping facilities for adult brood collection. Trapping schedules are coordinated among the various agencies with WDFW doing the actual trapping and handling at the Project.

Inspection procedures follow a given pattern, i.e., the inspector normally obtains the computer readings of the fishway main entrance gates, etc from the Control Room. These readings are then compared with staff gages and deck gages located at the entrances. These readings should be within 0.2 ft. If the gages vary by more than the 0.2 to 0.3 ft, then the project would calibrate the deck or Control Room gage. This was valid as long as the tailwater and entrance staff gages could be easily read or the tailwater elevation was somewhat flat.

East and West Fishways

In 2001, the side gates as well as the attraction flow water jets were closed on a permanent basis. The downstream entrance is now operated at the maximum opening of 8-ft at each fishway.

The head differentials reported at the **East** entrances for the 2001 season ranged between 1.1 ft and 1.6 ft based on the staff gage reading when feasible. The staff gages were unreadable on one occasion (same as in 1998-2000) and resulted in using a combination of staff and deck or computer reads to complete the inspection. The head differential readings at the **West** fishway entrances ranged between 1.6 ft and 1.0 ft. The staff gage readings were unreadable on one of the seven inspections, same as for East Ladder.

The head differential target of 1.5 ft ± 0.1 ft was met on four of the seven inspections at the East fishway and four of seven inspections at the West fishway entrances. The head differential was more than 1.0 ft on every occasion during the 2001 season. A major change of operation occurred on the West Fishway due to inordinate amounts of floating grasses that were drawn into the AWS system and then forced against the wall screens in the entrance area of the fishway. The differential between the supply pool and the fish entrance area reportedly became greater than 3.0 ft and as a result, the project began taking quick action to reduce this differential. The final setting was that the end gate was closed to 4.0 ft open and the head differential reduced from 1.5 ft to 1.0 ft. It operated in that mode from late August to the end of the fish passage season. This change in operations appeared to work satisfactorily and dropped the differential across the wall diffusers to an acceptable level.

Fish Ladder: At both fishways, the exits from the fish ladder were monitored for differential between the last fish ladder pool and the forebay elevation. Normally, the head differential ranges from 0.5 ft to 0.8 ft, depending on the forebay elevation. In 2001, differentials at the exits ranged from 0.6 ft to 1.0 ft. The exit from the fish ladder appeared clear of debris throughout most of the year; however, the final three inspections were reported with a differential of 0.9 ft to 1.0 ft. Expectations are that this higher differential measured across the trash rack was due to the greater amount of milfoil, elodea, and other grasses present in the Columbia River this season. The picketed leads at the counting stations appeared clear of debris during the inspection dates. The depth of water over the ladder weirs ranged from 0.9 ft to 1.3 ft at the West and East ladders. Criterion for depth of water over ladder weir is 1.0 to 1.2 ft.

Spill Basin: During 2001, spill was provided through the juvenile bypass system in bays 2, 4, 6, 8, and 10. No forced spill occurred this year.

Overall, **the East fishway entrance at Wells Dam performed satisfactorily throughout the adult fish passage season. As noted above, the West fishway was operated at reduced settings relating to head differential and Gate width from August to the end of the fish passage season.** Some changes or improvements that should be taken by the project include:

- Staff gages at the project should be cleaned on a regular basis, especially during periods of low tailwater elevation, as they were unreadable on several inspections.
- In 2002, Hydraulic evaluation or flow measurements will be taken to determine velocities through side and wall diffusers if flow conditions allow. The goal would be to improve flows through the collection channel to the start of the fish ladder weirs. Passage of fish through the entrance section and to the lower end of the fish ladder needs to be improved based on adult radio telemetry studies.
- More frequent checks of the ladder exits should be made later in the season due to higher grass and milfoil buildup; the differential was up to 1.0 ft across the racks during the final 3 inspections.
- Based on operation of the West Fishway, the project should implement a program to reduce the amount of grasses that can be entrained in either the pumped flow (tailwater) or the forebay flow that spins the turbine on the fish pumps.
- Lamprey passage should be investigated at the project. The fish counting ramp and viewing area appear very “unfriendly” for adult lamprey passage. In addition, the floor diffusers in the West entrance area had some fairly large gaps that should be covered or reduced in width to not allow fish to be stranded and lost through the cracks.
- Douglas County PUD should develop a spill schedule for levels of spill above the juvenile bypass spill requirement and approved by the Wells Coordinating Committee.

Table 13. Pertinent Data for Fish Facility Inspections in 2001 at WELLS DAM.

CRITERIA ITEMS		DATE OF INSPECTION						
EAST FISHWAY:		**1-May**	**24-May**	**26-Jun**	**24-Jul**	**27-Aug**	**28-Sep**	**16-Oct**
Head at main entrance (Target = 1.5ft)	ft	1.1	1.4	1.3	1.5	1.6	1.6	1.3
D/Stream entrance open (Criteria = 8-ft)	ft	8.0	8.0	8.0	8.0	8.0	8.0	8.0
Depth over ladder weir (Crit.= 1-1.2 ft)	ft	1.1	1.3	1.1	1.3	1.1	1.1	1.2
Ladder exit differential (Criteria = .6-.8ft)	ft	0.8	0.7	0.7	0.7	1.0	1.0	1.0
Staff gages clean/readable (yes or no)		yes	yes	yes	no	yes	yes	yes
Picket leads clean (yes or no)		yes	yes	yes	yes	yes	yes	yes
Auxiliary Fish Pump Speed (rpm)					57-60	60-70	60-65	57-61
Fishway entrance jets		Closed	Closed	Closed	Closed	Closed	Closed	Closed
WEST FISHWAY: (Criteria same as East)								
Head at main entrance	ft	1.5	1.4	1.5	1.6	1.0	1.0	1.0
Downstream entrance open	ft	8.0	8.0	8.0	8.0	6.0	4.0	4.0
Depth over ladder weir	ft	0.9		1.0	1.1	1.1	1.1	1.2
Ladder exit differential	ft	0.7		0.6	0.7	1.0	0.6	0.9
Staff gages clean/readable		yes	yes	yes	no	yes	yes	yes
Picket leads clean		yes		yes	yes	yes	yes	yes
Auxiliary Fish Pump Speed (rpm)					51-57	55-64	36-49	32-47
Fishway entrance jets		Closed	Closed	Closed	Closed	Closed	Closed	Closed
Comment Number (if applicable)		1	2		3	4	5	6

Comments:

1. Juvenile spill about 8.8 kcfs through 4 bays.
2. West fish ladder flow dropped to clean counting windows. Trapping bull trout 3d/wk at East Ladder trap.
3. The tailwater staff gages unreadable as water elevation lower than gages.
4. Buildup of trash on exit racks (both sides) and diffusion gratings (W Bank); End Gate closed to 4.0 ft and operating with 1.0 ft head differential on W. Bank.
5. Project operating with 4.0 ft end gate open and 1.0 ft head differential; potentially until the end of season.
6. Higher than normal differential at exit ladder; recommended cleaning if required. Same comment as 5 above.

SUMMARY OF RECOMMENDATIONS

General Recommendations

- Review adult radio telemetry study results; implement agreed-upon changes that would improve adult fish passage through the mainstem dams. Some key elements include passage through floating or fixed orifices along the powerhouse collection channels (**Note: several projects have closed their orifice gates in recent years, The Dalles, Lower Monumental, Little Goose, and scheduled for 2002, Priest Rapids and Wanapum dams)**, fallback at the dams, passage through main entrances and the fish ladders, and improving passage through junction pools or other areas where confused hydraulic conditions exist.

Other recommendations relating to adult fish passage have been reported at the FPOM committee meetings or in MCOL committee meetings during the 2001 season. Main issues relating to passage of adult fish have been addressed in a broad way via the Biological Opinion that was completed by NMFS due to the Endangered Species Act. Some obvious recommendations to improve fish passage conditions follow.

- Projects should assure that screening systems for the auxiliary water systems are adequate to reduce impacts that might occur when large amounts of debris are in the river.
- Projects should seal bulkhead slots along the powerhouse channel. This would reduce the amount of water that is basically wasted rather than going to the main entrances.
- Projects should fill or seal side entrance or other gates to reduce excessive noise from movement of gates currently set in these slots. This primarily pertains to spillway or powerhouse gates on the spillway side of the dam.
- Projects should assure that water-measuring devices are easy to read, and that includes at all water elevations during the year. Preferred staff gages would be those that can be cleaned easily or have bench marks available so sensor readings can be taken.
- Projects should automate and computerize fishway operations so that fish facilities can be kept within criteria limits through all ranges of flows and changes in operations.
- Projects should evaluate backup water supply sources to assure that adequate water is available to attract adult fish should the main water supply fail.
- Projects should complete approved spill schedules prior to the fish passage season.
- Prior to the adult/juvenile fish passage season, a pre-season meeting should be held to discuss previous years inspections and assess readiness for operation during the upcoming season. Issues at COE projects should continue to be discussed at the FPOM monthly meetings and individual meetings set with Douglas, Chelan, and Grant County PUDs .
- Projects should assure that diffuser gratings are intact and clear of debris before the main fish passage season begins and at some point during the season. This should be accomplished by video tape, divers or other acceptable means.
- All projects should have a plan of action on how to deal with removal of debris from the forebay of each dam. This would help assure that fish turbines/pumps, exits from the dams, picketed leads, or other areas would have less chance of plugging or causing damage to mechanical systems of the fishways or to the adult or juvenile fish passing the dams.
- Where known sharp projections or other obstacles are located in the fish ladders, collection or transportation channels, they should be removed expediently.
- Based on past performance of the fishway equipment, the projects should purchase spare parts of critical operating equipment that would allow “quick” fix during the fish passage season should equipment fail.
- Begin documentation of fish facilities with digital photographs of passageways, gratings, etc., to assure condition of facilities. This will be initiated at most COE `projects in 2002.

Appendix A.

Summary of fishway criteria for mainstem dams on the Columbia and Snake River.
Detailed criteria for COE and PUD projects can be found in the COE's Fish Passage Plan or in Detailed Fishery Operating Plans (adult criteria). This Appendix summarizes the general standards for the fishways at each project.

Entrance Head Differentials: 1.0 to 2.0 feet standard at all projects.
Wells, Wanapum, Priest Rapids, and Bonneville dams target 1.5 ft at some entrances, Priest Rapids and Wanapum target 1.25 ft.

Entrance Weir Gate Depths:

Bonneville - At the old powerhouse, maintain 8.0 ft or more depth at Gate 1/2 and 64/65; at the new powerhouse maintain 13' or > depth when tailwater elevation is above elevation 14 (sill = elev 1.0').

The Dalles, John Day (OR fishway), McNary (north shore), Ice Harbor (south, north ph) Lower Monumental, Little Goose (south), and Lower Granite (south, north ph) - 8 ft or more depth at Entrance Gates.

McNary (OR fishway) - 9.0 ft or > gate depths.

Rock Island (spillway entrance) - 8.5 ft or > gate depth.

Rock Island left bank, Little Goose north shore - 6.0 ft or > gate depth.

Lower Granite north shore, Little Goose north powerhouse - 7.0 ft or > gate depth.

Rocky Reach left powerhouse & spillway - 10' or > gate depth.

Entrance Wing Gate Openings:

Wells - 8.0 ft open end gate.

Rock Island - 2.0 ft open on center fishway side gate; 3.0 ft open on all right powerhouse entrance gates.

Rocky Reach - 3.0 ft open on right powerhouse gates.

Entrance (fixed-open) Gates: Maintain head differential of 1.0-2.0 ft

Bonneville - (spillway entrances)

Wanapum (all entrances)

Priest Rapids (all entrances)

Lower Monumental (south shore, SSE-2 is a permanent fix 6-ft open gate).

Turbine Unit Operating Priority: Specific to each dam (See year 2001 FPP for COE projects).
Spillway Operation: Specific to each dam (See 2001 FPP for COE projects and DFOP/LSOP and HCPs for PUD projects).
Collection or Transportation Channel Velocities: 1.5 to 4.0 fps at all projects.
Staff Gages or other Elevation Gages: At all projects, gages must be maintained throughout the fish passage season and readable at all elevations.

Fish Ladder
Depth of Water over Fish Ladder Weirs: 1.0 ft ± 0.1 ft; most projects use a 1.0 ft to 1.2 ft or 1.3 ft.
Head on Picketed Leads: Maximum of four inches at most projects (0.3 ft); 6.0 inches is required at Chelan PUD projects.
Head on Exit Trash Racks: Maximum of 0.5 ft greater than reading with a clean trash rack. Debris should be removed when significant amounts accumulate.

Appendix B (Photographs)

Bonneville Dam

Figure 1. Bradford Island Junction Pool
1. A-Branch fishladder, 2. B-Branch fishladder
3. Bradford Island fishladder
4. Ropes for tight wire walk across fishladder

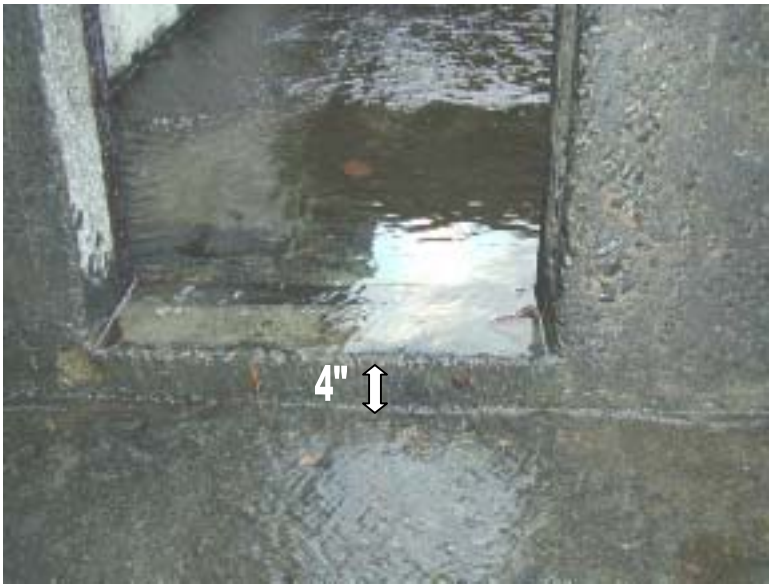

Figure 2. B-Branch Fish Ladder-Orifice about 4" lip on upstream side; about 10" drop on downstream side

Junction Pool

Bradford Fishladder

Figure 3. Junction Pool & B-Branch fish ladder

The Dalles Dam

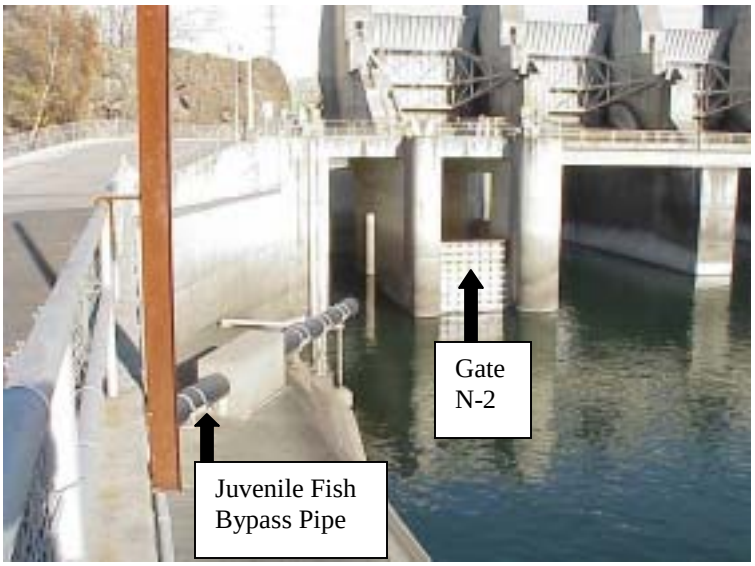

Figure 4. North Shore Fishway Entrance; Gate N-1 open; Gate N-2 remains closed

Figure 5a. North Shore PUD Trash Rack. Note dead adult fish.

Figure 5b. North Shore AWS Intake Trash Rack. Large build-up of Debris.

John Day Dam

Figure 6. North Shore Fish Ladder below Counting Station.

Figure 7. North Shore Fish Ladder. First Weir and Orifice located above Count Station. Diffusion gratings allow Auxiliary Water To be added at this point in the fish ladder.

Figure 8. South Shore Fish Ladder-Exit Section. Note: Wood jammed in exit slots.

McNary Dam

Figure 9. Beginning of powerhouse collection Channel with floating orifice gates 1 and 4 operating.

Figure 10. Oregon Shore Fish Ladders. Exit Section has overflow weirs that are adjustible; based on elevations.

Figure 11. McNary Spillway – Split Leaf Gate. This configuration was modified in 2001/2002 season to the normal spill gate.

Ice Harbor Dam

Figure 12. Ice Harbor Project

Figure 13. Eight fish pumps supply flow to the adult fish facilities at the South Fishway.

Figure 14. Diffuser Valves adjacent to the South Shore Junction Pool and fish ladder. Inspectors were: Larry Swenson and Bill Hevlin, NMFS and Mark Plummer, COE Project Biologist.

Lower Monumental Dam

Figure 15. North Shore Fishway Entrance Gates.

Figure 16. Near North Shore Main Entrances- former orifice Slot has been bulkheaded since 2000.

Little Goose Dam

Figure 17. Forebay area immediately above fishladder exit at Little Goose Dam.

Figure 18. Last exit pool and staff Gage used to measure head loss between this pool and the forebay of the project.

Lower Granite Dam

Figure 19. Operating floating orifice gate located adjacent to South Shore Main entrance gate.

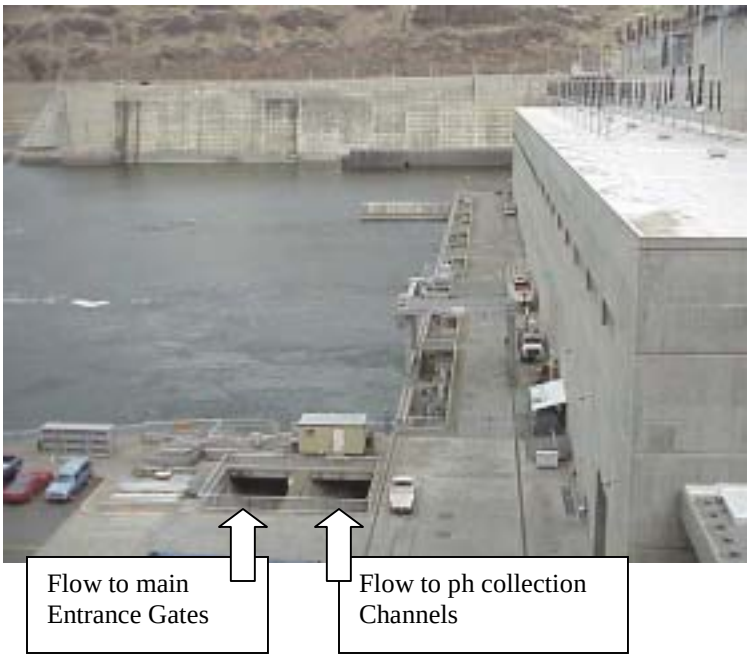

Figure 20. Side view of Lower Granite Dam.

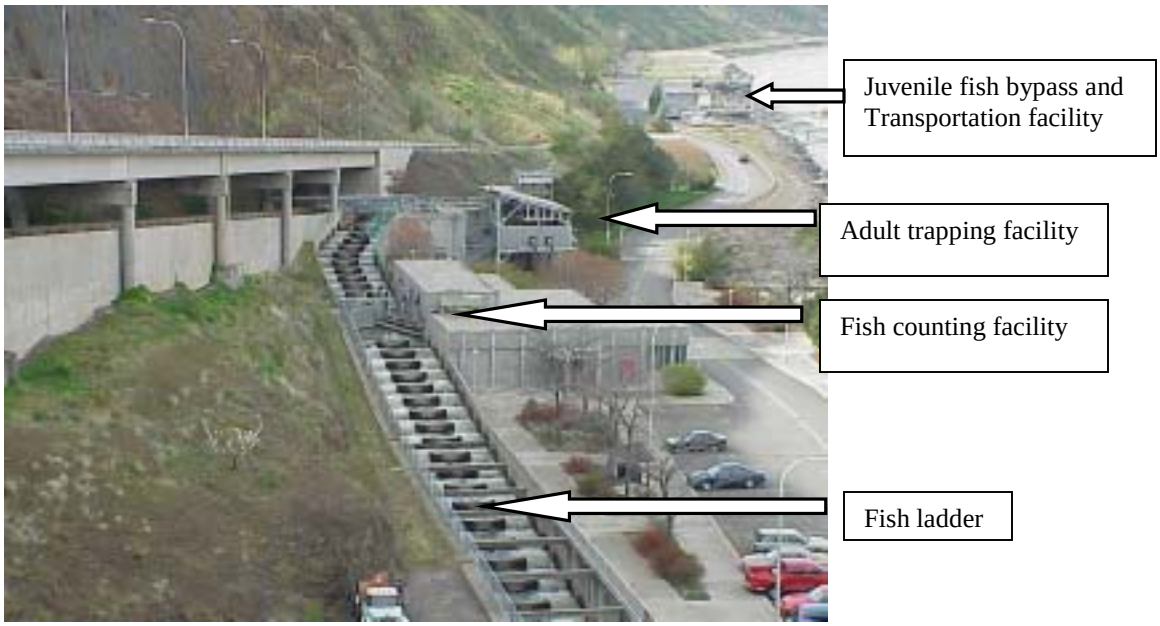

Figure 21. View of Lower Granite Dam Fish Ladder.

Priest Rapids Dam

Figure 23a. Surface Spill from Spillbay 22. Used to pass juvenile fish and adult fish below the project.

Figure 22. Underflow weirs in fish ladder exit section prior to the adult trap.

Figure 23b. Side view of Spillbay 22, looking from right bank to West end of powerhouse.

Wanapum Dam

Figure 24. Former fish counting site at the Left Bank

Figure 25a. Caisson housing cameras used to count fish passing the fish ladders. Flow passes through two orifices located in Exit Section of the fish ladder.

Figure 25b. Cameras mounted in Caisson and pointing outward through windows to view fish passing through the orifices.

Rock Island Dam

Figure 26. View of Rock Island's Spillway Section and the Middle Fishway.

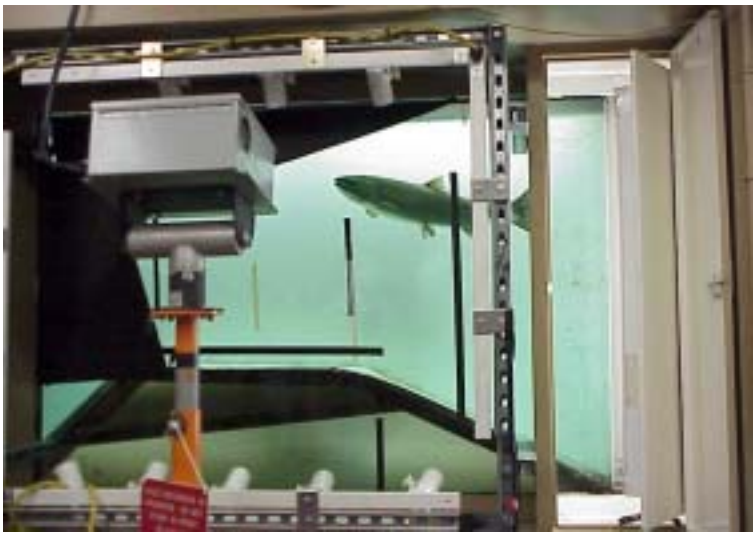

Figure 27. Right Bank fish counting window with video equipment in counting station.

Figure 28a. Right Bank Fishway-side diffuser screens with about 1 foot head loss across them.

Figure 28b. Right Bank Fishway- Head loss from the pumped and gravity water supply pool to the fish ladder

Rocky Reach Dam

Figure 29. Looking upstream at Rocky Reach powerhouse and spillbay.

Figure 30. New pilings placed in forebay of dam as part of new juvenile bypass system for Rocky Reach Dam.

Figure 31. Looking at present juvenile fish sampling Facility and adult fish ladder at Rocky Reach Dam.

Figure 32. Right powerhouse fishway entrance gates, RPE-1 and RPE-2. Both have 3-ft Wide entrance gate openings to attract Adult fish from the tailwater area.

Wells Dam

Figure 33. East Bank fish Ladder at Wells Dam

Figure 34. Note that the spill flows over the turbine area; i.e., no separate turbine and spill basin.

Figure 35. Stewart Mitchell and PUD operator at West Bank fishway Entrance reading staff and deck gages.

ACKNOWLEDGMENTS

Oregon Department of Fish and Wildlife, Washington Department of Fish and Wildlife, and National Marine Fisheries Service provided personnel to inspect adult fishways during the 2001 fish passage season. The Fish Passage Center appreciated the Agencies' commitment of providing fishway inspectors during the year. We recognize the time and commitment it takes from the individual inspector's normal activities to assure that fishways at the mainstem dams were inspected each month. Fishery agency personnel who participated in the inspection program during 2001 are listed below. For the 2001 season, there was one new inspector for the year, Josh Hanson, ODFW. Others listed have completed inspections from two to eleven years.

Agency	Inspector	Dams inspected
NMFS	**Ed Meyer**	**Bonneville**
NMFS	**Larry Swenson**	**McNary**
NMFS	**Melissa Jundt**	**Priest Rapids & Wanapum**
ODFW	**Doug Case**	**The Dalles & John Day**
ODFW	**Josh Hanson**	**Little Goose & Lower Granite**
WDFW	**Denise McCarver**	**Rock Island & Rocky Reach**
WDFW	**Glen Liner**	**Rock Island & Rocky Reach**
WDFW	**Steve Gacek**	**Rock Island & Rocky Reach**
WDFW	**Stewart Mitchell**	**Wells**
WDFW	**Steve Richards**	**Ice Harbor & Lower Monumental**

Project operations personnel and biologists from Portland and Walla District Corps of Engineers provided on-site assistance whenever necessary to assure that the agency inspector could thoroughly inspect the adult and juvenile fishways. The inspectors were appreciative of assistance provided by Project personnel at Corps of Engineers dams.

Grant, Chelan and Douglas Public Utility Districts were also very helpful in providing access and assistance for the fishway inspectors at the individual projects. This continued cooperation and assistance was greatly appreciated by the NMFS and WDFW inspectors and the Fish Passage Center.

Funding for the FPC staff coordination of the inspections was provided by the following fishery agencies: WDFW, ODFW, IDFG, USFWS, and NMFS.