Columbia-Snake River Irrigators Association
Eastern Oregon Irrigators Association
Northwest Irrigation Utilities

**Recommendation for Amendment
to the Northwest Power Planning Council
For the Columbia River Basin Fish and Wildlife Program**

Mainstem Plan:
A New Water Management Alternative For the Columbia River Basin

June 15, 2001

Columbia-Snake River Irrigators Association
Eastern Oregon Irrigators Association
Northwest Irrigation Utilities

DISTRIBUTION NOTICE

DATE: June 15, 2001

TO: Mr. Larry Cassidy, Chairman, NPPC
And Northwest Power Planning Council Members

FROM: Tom Mackay, President, CSRIA
Darryll Olsen, Ph.D., PNP, CSRIA Board Representative
Fred Ziari, President, EOIA
John Saven, Executive Director, NIU

SUBJECT: Recommendation for Amendment to the NPPC, Mainstem Plan
For the Columbia River Basin Fish and Wildlife Program:
A New Water Management Alternative for the Columbia River Basin

---

DISTRIBUTION:

1) Distribution Copies: Electronic Format to Council with Summary Technical Paper Included, and Complete Technical Support Materials Mailed in Binder Copy.

2) Additional Distribution Copies (Amendment and Summary Technical Paper) Provided to:

Gov. Gary Locke, WA
Gov. Dirk Kempthorne, ID
Gov. John Kitzhaber,OR
Gov. Judy, Martz, MT
WA State Legislative Leadership
Mr. Jim Waldo, Gov. Lockes's Water Policy Rep.
Mr. Tom Fitzsimmons, Director, WADOE
Pacific NW Congressional Delegation
Mr. Steve Wright, Administrator, BPA
Interested Parties

Columbia-Snake River Irrigators Association
3030 W. Clearwater, Suite 205-A, Kennewick, Washington, 99336

509-783-1623, FAX 509-735-3140
Columbia-Snake River Irrigators Association
Eastern Oregon Irrigators Association
Northwest Irrigation Utilities

DATE: June 15, 2001

TO: Mr. Larry Cassidy, Chairman, NPPC
and Northwest Power Planning Council Members

FROM: Tom Mackay, President, CSRIA
Darryll Olsen, Ph.D., PNP, CSRIA Board Representative
Fred Ziari, President, EOIA
John Saven, Executive Director, NIU

SUBJECT: Recommendation for Amendment to the NPPC, Mainstem Plan
For the Columbia River Basin Fish and Wildlife Program:
A New Water Management Alternative for the Columbia River Basin

---

EXECUTIVE SUMMARY

Proposed Amendment:

The proposed amendment for the Mainstem Plan is a "New Water Management Alternative for the Columbia River Basin," to improve throughout the Basin fish and environmental resources, to optimize for mainstem hydroelectric power production, and to provide for the social and economic needs of local and tribal communities.

Amendment Sponsored By:

- **Columbia-Snake River Irrigators Association**
- **Eastern Oregon Irrigators Association**
- **Northwest Irrigation Utilities**

Amendment Prepared By and Contact Person:

- **Prepared by Darryll Olsen, Ph.D., Resource Economist, Pacific Northwest Project Contact at 509-783-1623**

With Technical Contributions From:

- **Jim Anderson, Ph.D., Director, Columbia Basin Research Center, UW**
- **John Pizzimenti, Ph.D., Research Biologist, Harza Engineering Co., Portland, OR**

<u>Amendment Recommendation Areas:</u>

- **Mainstem River Operations for Flow Targets and Augmentation.**
- **Water Management within the Columbia River Basin Drainage Area.**
- **Comprehensive Approach to Tributary/Watershed Actions for Fish Improvements.**

<u>Key Amendment Actions:</u>

- **Recognize that the existing mainstem water management program is unsatisfactory—few, if any, measurable fish benefits, but with high economic costs to the region.**
- **Restructure the existing mainstem flow targets/augmentation program, creating no measurable fish detriments, but increasing mainstem hydropower production.**
- **Re-invest the economic benefits of a restructured hydro program into water management projects for tributaries and watersheds, providing new water storage options, more effective water right transfers and changes, and incentives for increased water efficiency.**
- **Redistribute new water management benefits among fish and environmental resources, and for use by local and tribal communities.**

<u>Consistency with NPPC Program Framework:</u>

<u>A. Habitat Based Program:</u>

- **The amendment relys on existing empirical data and studies to identify how water management actions can have an optimal benefit within two major habitat areas: the mainstem habitat corridor versus tributary or watershed habitat areas.**
- **Objectives are based on empirical salmon production—returning adult salmon--not elusive or uncertain measures of habitat improvement.**

<u>B. Power Supply Considerations:</u>

- **The amendment seeks to optimize mainstem hydropower production, while creating no measurable, negative impacts to fish.**
- **Hydropower production is increased, with the benefit of meeting growing regional and West Coast power market loads, while providing the funding to support new water management projects.**

<u>C. Long-Term Objectives and Strategies for the Mainstem:</u>

- **The amendment is based on long-term operations for the mainstem hydropower system, reflecting optimization needs to improve system operations.**
- **The amendment is based on long-term measures to enhance watershed habitat through site-specific water management projects.**
- **The amendment is based on long-term water management for the Pacific Northwest region, taking into account state control over water rights and the need to meet growing social and economic demand for water resources.**

- **The amendment is based on long-term economic planning, where existing financial resources are better used in the future to meet fish enhancement and hydropower production needs; the amendment is self-financed and sustained.**

AMENDMENT VISION STATEMENT

The principal water management strategy (for fish) within the Columbia-Snake River Basin, the flow targets/augmentation program, needs to be restructured, in order to improve biological benefits and reduce societal costs. A restructured program also has significant policy implications, eliminating the NMFS "no net loss" water policy that threatens the authority of states to govern water rights--as well as opening the way for new economic development options for tribal and local communities.

The present flow targets/augmentation program has no hydrological basis, lacks necessary biological justification, and is an extremely costly measure. By restructuring the program, it will be possible to ensure a higher level of measurable biological benefits, while moving toward collaborative fish enhancement actions among federal-state agencies, the tribes, and the direct economic stakeholders.

A restructured program will rely on the development of new water resource projects in the tributaries, enhanced water transfer and marketing programs, and additional water delivery efficiency improvements; and financial resources to implement new water projects made available from the generation of additional hydroelectric power.

The restructured flow targets/augmentation program will lead to greater certainty and verification for measurable fish benefits within the tributaries. Fish benefits for the existing program are uncertain and to a large extent cannot be verified within system operations. Fish benefits will be derived from generally improved habitat conditions and lower water temperatures within site-specific reaches of tributaries; fish will likely be in better physical condition when entering the mainstem environment.

By restructuring the existing flow targets/augmentation program, additional power revenues will be acquired from the federal hydroelectric power system. The river system will be managed under a new hydro regulation that offers additional power generation beyond the 1995-98, 2000 NMFS BIOP hydro regime. The additional revenues will be allocated to the construction/development of new water management projects.

Tribal participation will be encouraged in the development of new water projects. Also compensation strategies for the tribes could be explored to mitigate their potential fishing right impairments, or needs for economic development.

The restructured program will greatly reduce the costs of the current water management program, which is producing uncertain biological benefits. The end effect will be a much more

cost-effective program. A restructured program also will reduce future costs to society, the opportunity costs associated with the NMFS no net loss water policy.

The amendment sponsors believe that water should be the answer to our water management questions and issues, not made the problem.

AMENDMENT OBJECTIVES

A. Specific Biological Objectives:

The biological objective is to increase the number of returning adult salmon and steelhead--both natural and hatchery supplementation stocks--within individual tributaries and watersheds. This increase would be the direct result of water management measures within tributaries or watersheds, including new water storage projects, water transfers or changes, and water efficiency measures.

The specific objective is returning adult fish to site-specific areas of the Basin that can be--have a reasonable probability of being--enhanced via water management actions. The measure of returning adult fish must take into account changing inland climate and ocean conditions, as well as any other direct habitat measures that could be taken to improve fish runs. This means that adequate monitoring and evaluation must be undertaken to ensure that measurable fish benefits are verified.

At this time, the objective is to increase fish numbers for specific areas, but no set target or unit levels are recommended. Target levels may be established in the future given more experience with water management operations and other habitat improvement actions.

B. General Environmental and Social Objectives:

The existing flow augmentation program does not optimize water use for either survival benefits (fish benefits per unit of flow) or economic costs (benefit per dollar cost) to the river system. The New Water Management Alternative will provide for higher levels of measurable fish benefits and do so in a more cost-effective manner than the current flow management regime. The key objective is to maximize fish benefits via water management and do so in a cost-effective manner.

Resource managers need to change water management operations away from mainstem flow augmentation actions to improving habitat-water management conditions within selected tributaries and watersheds. Greater fish benefits may be obtained within tributaries, using less volumes of water. This factor has been generally ignored within the present flow augmentation program. Understanding and optimizing water use in tributary habitats will likely offer a more biologically productive, and cost-effective approach, to water management than past efforts.

Water management actions should defer to the existing authority of state water rights and should allow for "locally developed" solutions within specific watersheds. This could include implementing efficiency measures, enhancing water transfers and changes, and encouraging the development of new water storage projects to benefit both fish and economic interests. New water projects should provide water allocations that allow for environmental , economic, and tribal benefits--everyone should have access to benefits.

A broader social objective of the New Water Management Alternative is to reduce conflicts among interest and stakeholder groups within the region. The emphasis should be on identifying projects and actions that will both enhance environmental benefits and offer economic incentives.

IMPLEMENTATION STRATEGIES

The implementation of the New Water Management Alternative relies on two major components: A) a restructured flow augmentation program for the mainstem Snake and Columbia River system; and B) the development of a broad set of water management projects within the tributaries and watersheds.

A. Restructure the Existing Flow Targets/Augmentation Program.

The Council and federal water resource agencies shall develop a new hydro regulation for the Columbia Basin system, to review new project operations under a restructuring of the existing flow targets and augmentation program. This review shall be completed, as soon as possible, for implementation during 2002 and thereafter.

The new hydro regulation review shall focus on a restructured flow augmentation program that better reflects an optimization of the existing water resources. The hydro regulation shall deal with power, flood control, recreation, and fish protection operations.

For fish protection operations, the hydro regulation shall focus on pre-determined volumes (or blocks) of water dedicated for flow augmentation, rather than specific flow targets. The existing flow target approach has not been implemented according to sound scientific and technical principles, and it has created an overly complex operational structure. Water dedicated to flow augmentation will be based on maximum volume allocations, with implementation initiated during the 2002-2003 water-year period or as soon as possible.

The water volumes available for flow augmentation will be based on the following specifications, and *flow augmentation actions must be approved each year by the Northwest Power Planning Council:*

All Water-Year Conditions, Snake-Columbia River System:

- **The existing flow augmentation program for the spring period (primarily May-June) is eliminated for both the Snake and Columbia River systems.**

- **Any use of flow augmentation during the spring period will be for limited, experimental purposes (small volumes of water), and annual implementation approval will be required by the Northwest Power Planning Council.**

Low Water-Year Conditions, Snake River System:

- **For the summer period (July-August), water managers will provide for 0.0-0.5 MAF from the Brownlee Project and Upper Basin region (combined), consistent with state law and obtained from willing sellers or lessors. This action will be reviewed and approved annually by the Northwest Power Planning Council in order to consider fully changing hydro system conditions and/or constraints.**

- **For the summer period, water managers will provide for 0.2-0.9 MAF from Dworshak to be used for fall chinook migration and/or adult temperature control. This action will be reviewed and approved annually by the Northwest Power Planning Council in order to consider fully changing hydro system conditions and/or constraints.**

Low Water Conditions, Columbia River System:

- **For the summer period (July-August), water managers will provide for continued experimentation of 0-3.0 MAF, as reviewed and approved by the Northwest Power Planning Council on an annual basis.**

Average Water -Year Conditions (or above), Snake River System:

- **For the summer period (July-August), water managers will provide for 0.0-0.5 MAF from the Brownlee Project and Upper Basin region (combined), consistent with state law and obtained from willing sellers or lessors. This action will be reviewed and approved annually by the Northwest Power Planning Council in order to consider fully changing hydro system conditions and/or constraints.**

- **For the summer period, water managers will provide for 0.2-0.9 MAF from Dworshak to be used for fall chinook migration and/or adult temperature control. This action will be reviewed and approved annually by the Northwest Power Planning Council in order to consider fully changing hydro system conditions and/or constraints.**

Average Water-Year Conditions (or above) for the Columbia River System:

- **For the summer period (July-August), water managers will provide for continued experimentation of 0.0-3.0 MAF, as reviewed and approved by the Northwest Power Planning Council on an annual basis.**

Restructuring of the flow augmentation program will have the greatest deviation from past programs by eliminating the current spring flow augmentation regime. The limited benefits, if any, gained from the spring flow augmentation program could be off-set by a full smolt

transport regime, particularly during low water-year conditions. The new flow regime is expected to work injunction with the Council's revised mainstem fish passage program, taking into account smolt transportation measures, project spill regimes, and other juvenile fish passage measures at the mainstem hydro projects.

During the summer period, the restructured program will limit flow augmentation to a level not to exceed operations that occurred in the summer of 1994 (drought conditions). This regime will take into account both biological and economic demands on the river system.

Another important feature of this hydro regime program is *annual review by the Council members for implementation.* The program engenders flexibility within it to make changes that correspond to varying needs and conditions, as well as from improved information from monitoring and evaluation.

B. Water Resource Projects within the Tributaries and Watersheds.

Funding Mechanism:

By restructuring the existing flow targets/augmentation program, additional power revenues will be acquired from the federal hydroelectric power system. The river system will be managed under a new hydro regulation that offers additional power generation beyond the 1995-98, 2000 BIOP hydro regime.

The additional revenues--or a significant portion thereof--will be allocated to developing new water management projects within the tributaries and watersheds. Based on preliminary evaluations by the Council staff and others (NPPC Framework Process), the amount of funds available for this purpose is estimated to be about $40-400 million annually (NPPC Framework Process estimate updated to reflect current market rates).

By the spring of 2002, the Council shall initiate a program review process to determine how to allocate funding derived from the new hydro regime. This review process shall involve representatives from the respective governors' offices, representatives from local economic stakeholder groups, and tribal representatives.

As a key implementation guideline, the funding shall be provided via the Council and granted to state water resources agencies, working with local stakeholder groups and the tribes; and funding will be specifically directed toward water management projects within tributaries and watersheds.

The restructured program will greatly reduce the costs of the current water management program, which is producing uncertain biological benefits. It also will reduce future costs to society, the opportunity costs associated with the NMFS no net loss water policy.

Prioritizing and Targeting Water Management Projects:

The focus for water management will be on upper river and tributary fish enhancement projects. For example, such projects could be developed within key watersheds—such as the Yakima River Basin or the Upper Snake River Basin, and other areas. Potential projects should reflect a broad range of options for new water storage, water transfers and changes, and water efficiency measures.

Examples of water projects would include:

- **Developing new water storage projects within the upper tributaries; expanding the water storage capacity of existing projects; identifying areas where re-regulation reservoirs could be developed.**

- **Identifying change in water delivery diversion points that could provide both environmental and economic benefits.**

- **Improving water transfer and change legislation and/or administrative implementation (free of water right relinquishment requirements); expanding existing models of local management for water transfers and changes, such as water conservancy boards within Washington State; providing state funding to purchase water rights for targeted purposes.**

- **Providing funding for stakeholder identified water delivery efficiency projects, such as for irrigation district or municipal water systems; better evaluations of efficiency measures to understand direct changes to micro-hydrologic systems.**

By January 2002, the Council shall commission a fast-track review/study to identify and prioritize candidate projects for implementation. The review shall be presented to the Council by July 2002 or as soon as possible.

The new water resources projects shall be identified and developed jointly by state, economic stakeholder, and tribal interests. The new water projects would allocate water to fish, economic, and tribal needs.

The Council shall initiate water resources project funding by August 2002 based on its review of funding allocation protocol and the technical project review and priority study.

Tribal Role and Involvement:

In developing the new water resources projects, a portion of the power revenues from the restructured hydro regime shall be used to finance direct participation by the tribes. In effect, the tribes should become equity partners with the states and economic stakeholders in developing the new projects.

The current economic costs of flow augmentation can be transformed into venture capital for the tribes to become equity partners.

SCIENTIFIC FOUNDATION

Overview:

The river system benefits of flow augmentation are best estimated by relying on NMFS/UW data for flow-survival relationships (1993-2000 data), the CRiSP modeling analyses (which corroborate the NMFS/UW data), as well as other data and analyses being developed for fall chinook impacts. These data and analyses strongly suggest that the correlation between incremental flow changes and juvenile spring migrant survival is inelastic, and that the flow-survival benefits are very small. Also, flow augmentation benefits are best considered by examining the *within year* data relationships.

To date given the data available, estimated river system flow benefits--though limited by several factors—could favor fall chinook. But the uncertainty surrounding the effects of flow augmentation on overall fall chinook survival is great. Several factors are unclear or unresolved concerning direct inriver survival benefits within years, migration timing and flow conditions, temperature control and management, and the use of flow to improve transport collection efficiencies.

It is more clear that flow augmentation is a measure providing marginal survival benefits at best, while factors independent from the mainstem river system, such as ocean/inland climatic conditions, will govern total productivity levels.

Technical Review:

Beginning in 1993, NMFS and University of Washington researchers combined state-of-the-art PIT tag technology with sound statistical study design to quantify the relationship between juvenile migration survival and flow discharge in the Snake River. These data are now being collected under improved in-river test conditions of high spill and flow, as prescribed by NMFS in the 1995 BIOP. The NMFS have published findings to date, covering multiple-year flow conditions data.

The results of the multi-year juvenile survival data in the Snake River probably give us the most definitive picture of how flow affects spring chinook and steelhead migrating through the Lower Snake and Lower Columbia hydropower corridor. Key points from the NMFS data come readily to light.

For spring migrants, the *intra-year relationship* between flow rates and survival is very weak. When comparing juvenile survival between years, there is higher survival in years with higher flows. This parallels the findings of the original Sims and Ossiander study (1981), a study whose data have been criticized as statistically inadequate. Among other considerations, the inter-annual relationship seems to depend on the fact that there are very large differences in seasonal discharge from year-to-year; flow regimes much larger than we observe in weekly or monthly variations within each year. Examination of the data tends to suggest that it may not be the provision of higher flows that elicits the survival benefit.

In reviewing these data, it appears that for years when the average spring discharge is below 80-90 kcfs in the Snake River, survival is much lower than when it is above this value. But in

particular, the within year survival data strongly suggest that there is no apparent relationship between survival and flow. The biological or physical cause of why there is a strong between-year survival relationship, but no within-year relationship, is speculative; it is likely based in ecological factors that are well beyond the effects of the single flow rate variable.

For example, an examination of week-to-week survival of migrating juveniles indicates that the specific weekly discharge does not seem to greatly influence survival. That is, in examining the flow-survival relationship *within a specific year,* the same kind of strong relationship does not manifest, as noted between years. Is it possible that this situation exists because there is not a significant change in flows from week-to-week to elicit a survival response?

In answering this question, it can be observed that flows within a season can vary by as much as 50 to over 100 kcfs. Thus, it can be said that fish are exposed to highly variable flows within a year. It is not unusual to see Snake River flows at the beginning of the season at 40-60 kcfs and reach 120-140 kcfs as run-off proceeds. Snake River discharge history from 1994-1997 illustrates this point well. In 1994, flows began near 30 kcfs but never exceeded 100 kcfs--a very low flow year. In 1996, by contrast, flows began around 90 kcfs and peaked near 200 kcfs. In both years, flows fluctuated greatly within the season (sometimes within a week), yet no survival relationship emerged. Both years presented natural experimental opportunities for survival to show weekly fluctuations, because flow conditions were often highly variable week-to-week. But the survival data do not correspond to the flow variations.

This observation suggests that survival is not a function of week-to-week discharge; it is not the instantaneous flow condition that is providing a measurable survival benefit. Instead, it appears that it is the overall annual condition of low flow (drought) versus high-flow (flood) years. Seasonal, not daily or weekly, volume water discharge is a predictor (or a correlate) of annual in-river survival percentages--likely due to multiple variables stemming from wet seasons versus dry years.

Consider, as well, even if total seasonal discharge was the only variable driving survival--an unlikely assumption--is it possible to "turn a low-flow year into a high-flow year" by using reservoir storage and thereby increasing survival? If we compare the volume of water that passed Lower Granite Dam in the spring of 1994 and 1996, we find that total river flow in 1996 (14.6 MAF) was nearly twice that of 1994 (7.6 MAF). In order to make river conditions in 1994 resemble 1996, it would require an additional 7 MAF of flow augmentation. Currently, the total Snake River storage is about 12 MAF (System Operations Review estimate). Therefore, we would need to evacuate two-thirds of the entire storage in Idaho and release it in a two-month period. Even if this were hydrologically possible, it would leave negligible storage or available instream flows for other purposes; and the region would need to forego most uses for water later in the year, including fish and wildlife in the Middle and Upper Snake River.

It appears likely that the use of storage as a mitigation tool is relatively limited in how much increased in-river survival it can provide, within the mainstem hydropower corridor. A major objection to previous juvenile survival data has been inadequate in-river conditions to maximize in-river survival. NMFS has provided improved conditions to test this hypothesis since 1993, in the form of both higher spill and flow target levels.

Based on their own data, the NMFS recovery strategy should anticipate that survival of juveniles will vary year-to-year, and survival appears to be contingent especially on whether we anticipate a drought year and therefore low survival in-river. For now, it appears that flow as a tool to enhance in-river survival of spring migrants, within seasons, has severe limitations in the mainstem river; and that the survival benefits of simply drafting storage will be small, first by storage limitations themselves, and second by the survival benefits--no matter what we may be willing to pay biologically or economically in the way of upstream costs.

The benefits to fall chinook are less understood (undefined at the present time) during the summer migration season. But the debate on flow augmentation for Snake River fall chinook has a more recent historical review.

Studies demonstrate Snake River fall chinook survival to Lower Granite dam is correlated with release date, temperature, flows and turbidity. The analyses conclude that with the existing data, flow cannot be the identified as the operative variable affecting survival. The studies also demonstrate that the effects of these variables on survival are more pronounced through the river passage corridor above Lower Granite Dam than through the Lower Snake River.

Nevertheless, a review by the ISAB observed that the data also are inadequate to *deny* beneficial effects of flow augmentation. The ISAB report goes further to express a prevalent belief about flow. While no direct benefits have been observed, it is assumed that if flow positively correlates with variables that actually do affect survival, then flow augmentation may be valuable as long as the result is higher survival. While it is difficult to envision how small flow augmentations may be detrimental, the data does suggest a plausible scenario. Since fall chinook travel time is unrelated to flow or survival, flow does not affect exposure time to predators and its impacts must work indirectly through correlations with temperature and turbidity. For the seasonal pattern, high flow correlates with low temperature and so flow should correlate with survival, as the seasonal data indicate. However, flow augmentation from the Hells Canyon Reservoir complex is warmer than the Snake River and its tributaries, so flow produced through reservoir releases can be detrimental to smolt survival (Anderson 2001).

With science now showing that flow does not affect smelt survival in the hydro system, the flow-survival hypothesis has been reformulated as a qualitative statement that flow may affect survival in the estuary and the Columbia River plume. The NMFS flow white paper hypothesizes that deceased spring flows reduce the extent of the plume and the turbidity load, thus reducing the ability of the smolts to hide from predators. Studies conducted in the plume since 1998 show that predator numbers around the plume are important. In 1998, the plume was of a normal size, but the ocean environment was warm and contained a tremendous numbers of predators. Initial studies for 2001 revealed a significantly smaller plume in a cooler ocean virtually absent of predators. It is too early to conclude the impacts of river flow and ocean conditions on smolt survival in the plume, but the data clearly indicate that plume survival cannot be simply attributable to a single factor, be it flow, ocean temperature, or predator abundance. Statements about the impacts of flow on estuary and plume conditions are speculations that do not constitute a justification for flow augmentation, but they do point to needed areas of research.

This does not mean that evaluation of the flow augmentation must wait for another decade of research. Analyses to evaluate flow augmentation can be performed with the available information. Specifically, a sensitivity analysis can be developed to ascribe a range of expected survivals for different levels of flow augmentation. However, an analysis must have an ecologically realistic foundation. Otherwise spurious regressions of flow against survival, such as was done with the Sims and Ossiander data, will continue to misrepresent the science.

In summary, the history of the flow survival research and policy contain many details but the essential elements are this: In the 1980s, limited data suggested that flow had a strong effect on fish survival. Using this information and the intuitive belief that flow is good for fish, fishery managers embarked on a water budget program with the hope that fish survival would dramatically increase. However, fish stocks declined and fishery managers incrementally increased augmentation to its current level, which is five times the initial level in the 1980s (Olsen et al. 1998). Today, with two decades of research, the flow survival hypothesis envisioned in 1980 can be rejected. Furthermore, the hypothesis relating flow augmentation to SARs through mechanisms that occur outside the hydrosystem are likely untestable with the current technology. However, using the available data and ecologically-based models it should be possible to characterize the upper and lower benefits of flow augmentation on salmon.

It is essential that the limits of flow augmentation be characterized quantitatively, especially when the cumulative impacts are considered. While an incremental increase or decrease in augmentation may have a small biological effect, it does not follow that the cumulative effect is significant. For example, daily fluctuations in project flows alone may significantly overshadow any future impacts caused by either seasonal water withdrawals or flow augmentation attempts. Not quantifying what is meant by "cumulative impact" can inadvertently imply that without flow augmentation, or with new water withdrawals, the river would "go dry."

It should be further underscored that any flow augmentation program effectiveness is directly impacted by the collection efficiency of the smolt transportation program. Under a full or "maximized" transport collection program, the flow augmentation benefits within the mainstem corridor become very limited. For example, in the case of Snake River spring chinook collection at Lower Granite and Little Goose dams, 80% collection efficiencies will leave less than 5% of the migrating fish within the river system (below Little Goose Dam). If transport collection efficiencies improve at the McNary Project, then the flow benefits for Mid-Columbia fall chinook will decrease as well. And as technical modifications are made at the collection facilities to improve fish guidance, the upriver effects of flow augmentation to improve fish guidance are diminished.

Finally, in contrast to some of the biological impacts, the economic trade-offs of flow augmentation are more predictable. Flow augmentation does increase costs to the hydropower system--one of the single largest costs of the salmon recovery program--and it can create significant costs to water users, through either direct water curtailments or abrogating state water permits. The direct and opportunity costs of the flow augmentation program represent hundreds-of-millions of dollars to the regional economy.

Key Supporting Technical Reports/Materials Used to Prepare Amendment:

The following technical documents are included with this amendment as supporting materials:

- **Anderson, J. J. 2001. History of the Flow Survival Relationship and Flow Augmentation Policy in the Columbia River Basin. Columbia Basin Research Center, University of Washington, Seattle, Washington, June.**

- **NMFS, 2001. NMFS Survival Study Update: 2000 Results. Presentation materials provided to the Northwest Power Planning Council, February 7, 2001.**

- **Olsen, D., J. Anderson, and P. Pizzimenti. 1998. The Columbia-Snake River Flow Targets/Augmentation Program, A White Paper Review with Recommendations for Decision makers. Prepared by the Pacific Northwest Project, Kennewick, Washington.**

IMPLEMENTATION PRINCIPLES

The amendment sponsors advance the following general principles in recommending the New Water Management Alternative.

Water Management and Hydro System Operations:

The primary hydro issue facing the Northwest is how to manage water, rather than a system configuration debate that includes dam breaching.

The future resource issue will not be dam removal, but how to manage water. Dam breaching costs will exceed the region's willingness-to-pay for uncertain fish benefits; but some groups may assert that these costs should serve as the region's "avoided cost" to set the level of future fish program expenditures. Dam breaching and reservoir drawdown alternatives will be eliminated from further review or consideration.

The end-effect of the existing flow targets/augmentation program is the misallocation of water; water is being used "speculatively," at best, with no demonstration of beneficial use--either biological or economic. Water management should be optimized based on measures of biological-environmental benefit and cost-effectiveness.

New water management projects will be evaluated for both environmental benefits--particularly fish protection and enhancement--and how they enhance the social and economic needs of local and tribal communities.

Regarding mainstem hydro system passage, the Council shall rely on some mix of "share the risk" practices during the years ahead--a mix of juvenile fish transportation, spill programs, and improved turbine/bypass survival passage measures. These measures will change and evolve through time based on careful monitoring and evaluations.

Regional Water Policy and Economic Needs:

There can be a restructured flow augmentation program--because several MAF provided even in low water-years has no, or no measurable, biological value. The NMFS flow program cannot demonstrate beneficial use.

The restructured flow augmentation program would allow for additional growth of water use for municipal, industrial, and irrigation sectors--use the "saved" water from the flow augmentation program for beneficial uses (several MAF would be available, at least 3-6 MAF).

Also, water transfers (marketing) can be pivotal in reducing the demand for new water permits in the future and providing economic incentives for efficiency improvements Pragmatic economic incentives will rival regulatory "hammers" or theory any day. The criteria for whether water right holders or the state should receive "saved" water should be the funding source--private or public funds.

The great water right as a property right versus public trust debate is fine for academic discourse, but property rights are what make the water system function. Water rights provide for economic incentive, flexibility, and productivity; and financial certainty. Lenders, bankers, and public bond purveyors want property rights, not public trust dogma. A water right must be functionally treated as a property right, or the water supply system will rapidly break down.

Tribal Interests and Participation in Water Projects:

In considering tribal interests within the political economy of salmon recovery, there should be a recognition that tribal commercial fisheries--even with catch improvements--represent a very limited solution to tribal economic development--direct net benefits of a few million dollars annually, at best. Other activities and ventures will be needed, and water management projects can open the door to new economic development options.

But in considering tribal interests, there should be a recognition that tribal ceremonial and subsistence (local retail) fisheries in Zone 6 can be maintained and perhaps enhanced. This is important because these fisheries are an empirical expression of protecting tribal property rights, which could hold significant economic value--but the property right will focus on water.

In considering tribal interests, economic stakeholders should view tribal fisheries as an impaired property right. This could, or should, lead to discussions to consider opportunities to allow the tribes to become vested interests in long-term economic development projects, such as new water management projects.

CONCLUDING COMMENTS

The amendment sponsors applaud the Northwest Power Planning Council members and our Northwest state governors for an opportunity to submit recommendations to the new Columbia Basin Fish and Wildlife Program.

The sponsors believe that the centerpiece for the new fish program can and should be a New Water Management Alternative for the Columbia River Basin. This program can become reality through the leadership of the Northwest Power Planning Council.

History of the Flow Survival Relationship and Flow Augmentation Policy in the Columbia River Basin

A Working Paper Prepared By:
James J. Anderson
Columbia Basin Research
School of Aquatic and Fishery Sciences
University of Washington
Seattle, Washington
June 2001

Flow augmentation and flow targets have been central programs in Columbia River salmon management for twenty years. Over this time, water requests have increased from 3.75 MAF in 1983 when the Water Budget was established (NPPC 1983) to between 13 and 16 MAF in the 1995 and 2000 NMFS Biological Opinions (NMFS 1995a, NMFS 2000a). Over the same period, the science on the effects of flow grew from a single graph between smolt survival and Snake River flow, to a body of information involving the entire life cycle of salmon. Whereas the scientific justification of flow augmentation has become more uncertain, the management policy has become more established and simplified. This paper reviews the history of the flow survival research to provide a perspective on the evolution of the flow policy.

Important policy decisions and research that support and challenge a strong flow augmentation hypothesis are illustrated in Table 1. The original flow augmentation, known as the Water Budget, was implemented in 1983 because ten years of survival studies suggested a strong increase in fish passage survival could be obtained from modest increases in flow through the hydrosystem. This survival relationship was based on the now infamous Sims and Ossiander data (1981), which was a plot of seven years (1973-1979) representing yearly averaged flows at Ice Harbor Dam against the per project survival of spring chinook and steelhead smolts from the Snake River (Figure 1). The relationship, used in a model, suggested spring chinook survival would increase by 180% with a 47 kcfs increase in flow at Ice harbor Dam (CBFWA 1990).

Table 1. History of Flow-Survival Relationship Key Studies and Program/Plans

Year	Evidence for flow-survival hypothesis and policy	Evidence against flow survival hypothesis and policy
1981	**Sims and Ossiander 1981** (73-79 Spring Chinook Sstudies)	
1983	**NPPC 1983** Fish & Wildlife Program*	
1990	**CBFWA 1990** Integrated System Plan	
1992	**Petrosky 1992** (Adult Returns Rates Correlated with water Travel Time in Snake River)	**Marsh and Achord 1992** (First PIT-tag Study Shows High Survival with Low Flow)
1993	**Hilborn et al. 1993 ; Berggren and Filardo 1993** (Fall Chinook Flow-Travel Time Relationship)	
1994	**Cada et al. 1994** (Review from Several Systems Conclude Flow and Other Factors Affect Survival)	**Giorgi et al. 1994** (No Fall Chinook Flow-Travel Time Relationship) **Olsen and Richards 1994** (Ocean Conditions affect West Coast Chinook)
1995	**NMFS 1995** BiOp* (Proposed Flow Targets)	**Williams and Matthews 1995** (1970s, Low survival from Trash at Dams) **Skalski et al. 1996** (Fall Chinook Survival Depends on Comparison Stock)
1997		**Smith et al. 1997a** (1993-1997 Data Shows No Within-Year Flow Survival Relationship for Spring Chinook) **Giorgi et al. 1997 ; Smith et al. 1997b** (No Within-Year Flow Survival Relationship in Fall Chinook) **Mantua et al. 1997** (Ocean Regime Shifts Alter Salmon Production is an Alternative Reason for Stock Decline)
1998	**Marmorek et al. 1988** (FLUSH Passage Model Predicts Strong Flow Survival Relationship)	**Marmorek et al. 1988** (CRiSP Passage Model Predicts Weak Flow Survival Relationship) **Olsen et al. 1998** (Comprehensive Review of the Flow Program Questioning Policy, Hydrology, Biology, and Economics)
2000	**NMFS 2000a** BiOp* (Continues with Flow Targets and Flow Augmentation Proposed in 1995 BiOP)	**NMFS 2000b** (No Flow Survival Relationship for Snake River Spring Migrants for 1995-1999) **NMFS 2000a** SIMPASS (Smolt Passage Model Survival Depends On Distance not travel time) **Anderson et al. 2000; NMFS 2000b** (Snake River Fall Chinook Survival to LGR Dam Not Related to Travel Time, Survival has Highest Correlation with Release Date and Water Quality Parameters, which covary)
2001		**Muir et al. 2001** (Hatchery Chinook Survival Varied Inversely with Distance to LGR Dam. Hydrosystem Survivals in 1990S Equal Survivals in the1960s and Little Mortality Occurs in Reservoirs) **Williams et al. 2001** (Survival Increases from 1970s to 1990s not Accompanied by Change in Flow) **Anderson and Zabel** (Model Shows Smolt Survival Depends on Distance)

* Fish migration and recovery programs.

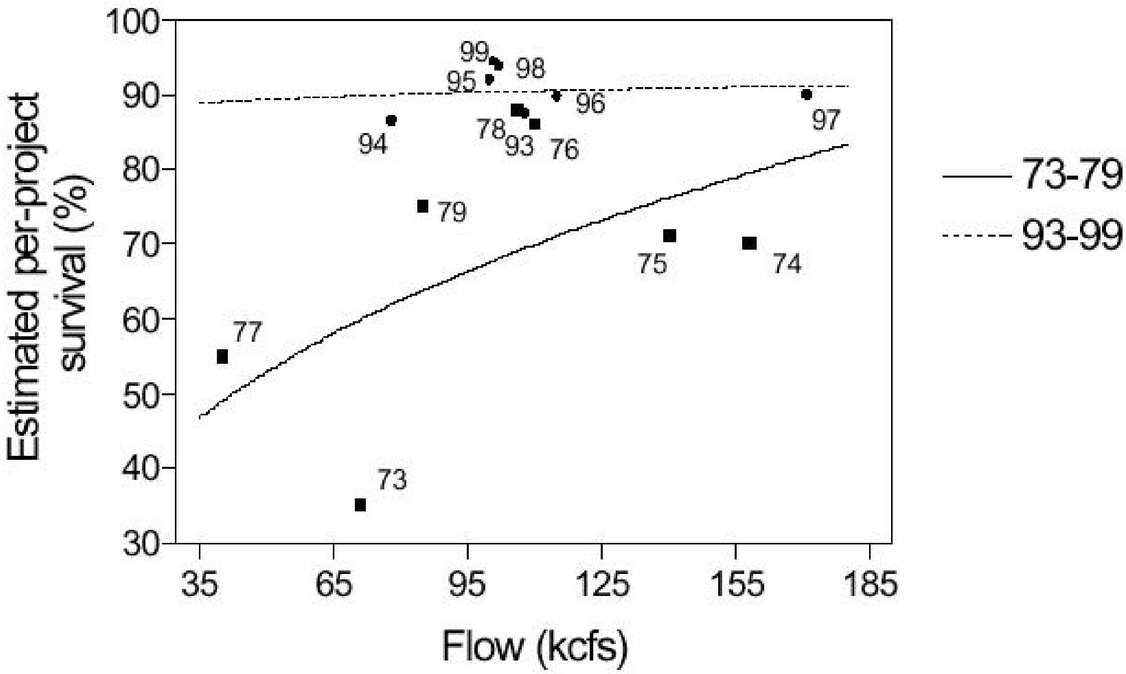

Figure 1. Historical and recent estimates of per-project survival (%) for yearling chinook salmon vs. index of Snake River flow (kcfs). Curves depict fitted nonlinear regression equations describing relationship between flow and survival in the two time-periods. Early period data from Raymond (1979) and Sims and Ossiander (1981). Graph from NMFS (2000b).

In the 1980s, research seemed to support the hypothesis that flow determined smolt survival and suggested a mechanism through smolt travel time. Petrosky (1992) demonstrated the smolt to adult survival (SAR), decreased as Snake River water travel time increased (Figure 2). A paper by Berggren and Filardo (1993) showed flow and smolt travel time were significantly related. Hilborn (1993) compared SARs of spring chinook from the Upper and Lower Columbia, and concluded the SAR difference between the two reaches was greater for years with lower flows. From these studies, the hypothesis emerged that flow affected survival through travel time: higher flows meant shorter travel times, which meant less exposure to predators and therefore higher survival. Cada et al. (1994) reviewed a range of studies and suggested other factors were also of importance, especially temperature. With these reports, NMFS justified flow augmentation primarily thorough the effect of flow on fish travel time (NMFS 1995b). However, the link between travel time and survival was hypothetical: longer exposures to predators were assumed to increase mortality. The hypothesis also involved temperature: fish arriving at projects later with higher temperatures would encounter more active predators and could have lower bypass efficiency causing more fish to pass through turbines. In the 1995 Biological Opinion, NMFS used travel time as one of the main performance measures to establish flow targets (NMFS 1995a).

From these reports and analyses emerged the beliefs that flow and travel time were the major factors affecting smolt to adult survival, and that small increments of flow augmentation within a season would achieve the same effect on survival as the year-to-year variations in flows. However, the Water Budget contained an untested and questionable assumption that incremental flow augmentation within a year has the same effect on survival as the year-to-year changes in flow that are also accompanied by year-to-year changes in climate and ocean conditions.

Fish managers also proposed removing the four lower Snake River dams, which would remove the dam passage mortality as well as improve survival by decreasing water travel time (NMFS 1995a).

During the 1980s, while fishery managers were implementing the Water Budget, the PIT-tag marking system was developed, which allowed scientists to measure smolt survival with greater precision and accuracy within the migration season. With this system, researchers began a decade-long test of the flow survival relationship. The first results were obtained from Little Goose Reservoir in 1992, which was a low flow year similar to 1973. Researchers expected survival to be low, but surprisingly, the PIT-tag measured survival was higher than any survival in the Sims and Ossiander study. It is noteworthy that in the 1995 analysis of flow, NMFS rejected the 1993 and 1994 PIT tag studies, which showed no flow survival relationship (NMFS 1995b). However, after eight years, the conclusion from the PIT-tag studies is unequivocal; flow survival and travel time survival relationships for spring chinook and steelhead migration through the hydrosystem were not found (NMFS 2000b, Muir et al. 2001). The flow survival hypothesis must be rejected. Furthermore, both PIT-tag studies (Muir et al. 2001) and theory (Anderson and Zabel, in review) suggest smolt survival depends primarily on distance traveled and involves smolts migrating past territorial predators, which produces a gauntlet effect

As a final note, the strong flow survival relationship shown in the Sims and Ossiander data (Figure 1) depended on low survivals in the two drought flow years, 1973 and 1977. It is now believed that in these years, passage conditions at Snake River dams were poor (Williams and Matthews 1995). The present day smolt survival through the eight dams of the current hydro system is equal to survival in the 1960s, when the Snake River smolts passed only four dams (Anderson 2000, Williams et al. 2001).

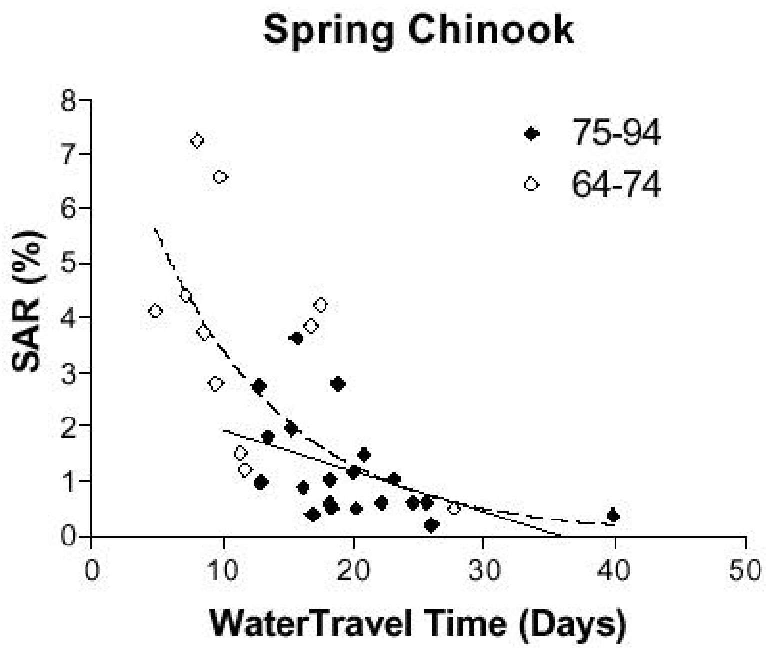

Figure 2. Regressions of smolt-to-adult returns versus water travel time for Snake River spring/summer chinook salmon for the 1964-1994 smolt migration (after Petrosky and Schaller 1998). The dashed line represents the regression line for the entire period; the solid line is for the years 1975-1994. From NMFS(2000b).

Even though the evidence against a flow survival relationship was steadily building, fishery managers up through 1998 supported a strong flow survival relationship (Marmorek et al. 1998a). In particular, the PATH work group, charged with evaluating the impact of dam removal on salmon, favored the FLUSH smolt passage model, which predicted hydro system survivals between 5 and 20%. The alternative model, CRiSP predicted survivals between 15 and 50% (CBR 2000). With the overwhelming evidence in 1999, fishery managers abandoned the FLUSH model in favor a simplified passage model, SIMPAS (NMFS 2000c). Both SIMPAS and CRiSP were calibrated with the PIT-tag survival studies and are in basic agreement that hydro system survival is high.

Although the strong flow survival relationship has been virtually rejected, the results of PATH, which significantly depend on the FLUSH model, were used in developing the 2000 Biological Opinion (NMFS 2000a).

The second intended benefit of the flow program involves a hypothesized effect on adult returns, as expressed through an SAR water travel time relationship (Petrosky 1992). NMFS, noting problems with the Petrosky study, reevaluated the relationship using data representative of the current fish passage environment and found a weaker relationship between SAR and water travel time than proposed by Petrosky (Figure 2) (NMFS 2000b). With the hypothesized flow survival relationship disproved for smolts, flow augmentation now depends on a possible relationship with SAR. This support is equivocal though: the NFMS flow survival white paper states "Correlation does not necessarily imply causation (Sokal and Rohlf 1981), and higher SARs associated with higher flows does not necessarily indicate the SARs can be increased by adding more flow to the river" (p 53 NMFSb). However, with this caution expressed, NMFS continued to call for flow targets: "These results support management actions to provide flows of at least 85 kcfs in the Snake River and 135 kcfs in the upper (mid-) Columbia River during spring and 200 kcfs in the lower Columbia River during the summer" (page 57 NMFS 2000b). Finally, in support of the targets, NMFS concluded that although a direct flow survival relationship cannot be established by data, it does not preclude benefits of flow augmentation because increased flows may improve survival outside the hydro system as a result of earlier arrival to the estuary, improved estuary conditions and reduced delayed mortality (page 58, NMFS 2000b).

The debate of flow augmentation on Snake River fall chinook has a more recent history. Studies demonstrate Snake River fall chinook survival to Lower Granite dam is correlated with release date, temperature, flows and turbidity (Anderson et al. 2000, Dreher et al. 2000, NMFS 2000b). The analyses conclude that with the existing data, flow cannot be the identified as the operative variable affecting survival. The studies also demonstrate that the effects of these variables on survival are more pronounced through the river passage corridor above Lower Granite Dam than through the Lower Snake River.

However, a review by the ISAB observed that the data also are inadequate to *deny* beneficial effects of flow augmentation (ISAB 2001). The ISAB report goes further to express a prevalent belief about flow. While no direct benefits have been observed, it is assumed that if flow positively correlates with variables that actually do affect survival, then flow augmentation may be valuable as long as the result is higher survival. While it is difficult to envision how small flow augmentations may be detrimental, the data does suggest a plausible scenario. Since fall chinook travel time is unrelated to flow or survival, flow does not affect exposure time to predators and its impacts must work indirectly through correlations with temperature and turbidity. For the seasonal pattern, high flow correlates with low temperature and so flow should correlate with survival, as the seasonal data indicate. However, flow augmentation from the Hells Canyon Reservoir complex is warmer than the Snake River and its tributaries, so flow produced through reservoir releases can be detrimental to smolt survival (Anderson 2001).

With science now showing that flow does not effect smolt survival in the hydro system, the flow survival hypothesis has been reformulated as a qualitative statement that flow may affect survival in the estuary and the Columbia River plume. The NMFS flow white paper hypothesizes that deceased spring flows reduce the extent of the plume and the turbidity load, thus reducing the ability of the smolts to hide from predators (page 54 NMFS 2000b). Studies conducted in the plume since 1998 show that predator numbers around the plume are important. In 1998, the plume was of a normal size, but the ocean environment was warm and contained a tremendous numbers of predators. Initial studies for 2001 revealed a significantly smaller plume in a cooler ocean virtually absent of predators (E. Casillas, personal communication). It is too early to conclude the impacts of river flow and ocean conditions on smolt survival in the plume, but the data clearly indicate that plume survival cannot be simply attributable to a single factor, be it flow, ocean temperature, or predator abundance. Statements about the impacts of flow on estuary and plume conditions are speculations that do not constitute a justification for flow augmentation, but they do point to needed areas of research.

This does not mean that evaluation of the flow augmentation must wait for another decade of research. Analyses to evaluate flow augmentation can be performed with the available information. Specifically, a sensitivity analysis can be developed to ascribe a range of expected survivals for different levels of flow augmentation. However, an analysis must have an ecologically realistic foundation. Otherwise spurious regressions of flow against survival, such as was done with the Sims and Ossiander data, will continue to misrepresent the science.

The history of the flow survival research and policy contain many details but the essential elements are this: In the 1980s, limited data suggested that flow had a strong effect on fish survival. Using this information and the intuitive belief that flow is good for fish, fishery managers embarked on a water budget program with the hope that fish survival would dramatically increase. However, fish stocks declined and fishery managers incrementally increased augmentation to its current level, which is five times the initial level in the 1980s (Olsen et al. 1998). Today, with two decades of research, the flow survival hypothesis envisioned in 1980 can be rejected. Furthermore, the hypothesis relating flow augmentation to SARs through mechanisms that occur outside the hydro system are likely untestable with the current technology. However, using the available data and ecologically-based models it should be possible to characterize the upper and lower benefits of flow augmentation on salmon.

It is essential that the limits of flow augmentation be characterized quantitatively, especially when the cumulative impacts are considered. While an incremental increase or decrease in augmentation may have a small biological effect, it does not follow that the cumulative effect is significant. For example, daily fluctuations in project flows alone may significantly overshadow any future impacts caused by either seasonal water withdrawals or flow augmentation attempts. Not quantifying what is meant by “cumulative impact” can inadvertently imply that without flow augmentation, or with new water withdrawals, the river would “go dry.”

References

Anderson, J. J. (2000) Decadal climate cycles and declining Columbia River salmon. In Proceedings of the Sustainable Fisheries Conference, Victoria, B.C," ed. E. Knudsen. American Fisheries Society Special publication no. 2x. Bethesda, MD.

Anderson, J. J. R. H. Hinrichsen, and C. Van Holmes. 2000. Effects of flow augmentation on Snake River Fall Chinook. 64 pages. Report to the Committee of Nine and the Idaho Water Users Association D.

Anderson, J. J. 2000. Heat Budget of Water Flowing through Hells Canyon and the Effect of Flow Augmentation on Snake River Water Temperature.

Anderson,J.J. and R.W. Zabel (in review). Travel time and distance dependent smolt survival: model, observations and implications. Transactions of the American Fisheries Society.

Berggren, T.J., and Filardo, M.J. 1993. An analysis of variables influencing the migration of juvenile salmonids in the Columbia River basin. N. Amer. J. Fish. Manag. 13: 48-63.

CBFWA. 1990. Integrated system plan for salmon and steelhead production in the Columbia River Basin. Prepared by the Agencies and Indian Tribes of the Columbia Basin fish and Wildlife Authority. 90-12.

Cada, G.F., M.D. Deacon, S.V. Mitz, and M.S. Bevelhimer. 1994. Review of information pertaining to the effect of water velocity of the survival of juvenile salmon and steelhead in the Columbia River basin. Prepared for Chip McConnaha, Northwest Power Planning Council, Portland, Oregon.

CBR (Columbia Basin Research) 2000. Columbia River Salmon Passage Model CRiSP 1.6 theory and Calibration. CBR at University of Washington.

Dreher, K.J., C.R. Petrich, K.W. Neely, E.C. Bowles, and A. Byrne. 2000. Review of survival, flow, temperature, and migration data for hatchery-raised, subyearling fall chinook salmon above Lower granite Dam, 1995-1998. Idaho Department of Water Resources, Boise.

Giorgi, A. E., D. R. Miller, and B. P. Sanford. 1994. Migratory characteristics of juvenile ocean-type salmon, *Oncorhynchus tshawytscha,* in the John Day Reservoir on the Columbia River. Fishery Bulletin 92: 872-879.

Giorgi, A. E., T. W. Hillman, J. R. Stevenson, S. G. Hays, and C. M. Pevin. 1997. Factors that influence the downstream migration rate through the hydroelectric system in the Mid-Columbia River basin. North American Journal of Fisheries Management 17: 268-282.

Hilborn, R., R. Donnelly, M. Pascual, and C. Coronado-Hernandez. 1993b. The relationship between river flow and survival for Columbia River chinook salmon. Draft Report to U.S. DOE, Bonneville Power Administration, Portland, Oregon.

ISAB (Independent Scientific Advisory Board). 2001. Review of Lower Snake River Flow Augmentation Studies ISAB 2001-4.

Mantua, N.J., S.R. Hare, Y. Zhang, J.M. Wallace and R.C. Francis. 1997. A Pacific interdecadal climate oscillation with impacts on salmon production. Bulletin of the American Meteorological Society 78:1069-1079.

Marmorek, D. R. and C. N. Peters. editors. 1998. Plan for analyzing and testing hypotheses (PATH): Preliminary decision analysis report on Snake River spring/summer chinook. Prepared by ESSA Technologies, Ltd. Vancouver, British Columbia.

Marsh, D. M. and S. Achord. 1992. A comparison of PIT-tagged spring and summer chinook salmon detections rates with Snake River flows at Lower Granite Dam. National Marine Fisheries Service. northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle Washington, 98112-2097. 5 p.

Muir, W.D., Smith, S.G., J.G. Williams Hockersmith, and Skalski, 2001. Survival Estimates for Migrant Yearling Chinook Salmon and Steelhead Tagged with Passive Integrated Transponders in the Lower Snake and Lower Columbia Rivers, 1993–1998. North American Journal of Fisheries Management 21(2) 269-282.

NMFS (National Marine Fisheries Service). 1995a. Endangered species Act- Section 7 consultation Biological Opinion; Reinitiation of Consultation on 1994-1998 operation of the Federal Columbia River Federal Power System and juvenile transportation program in 1995 and future years. NMFS (National Marine Fisheries Service).

NMFS (National Marine Fisheries Service) 1995b. Basis for flow objectives for operation of the Federal Columbia River Power System (February 1995). National Marine Fisheries Service and the National Oceanic and Atmospheric Organization.

NMFS (National Marine Fisheries Service). 2000a. Endangered species Act- Section 7 consultation Biological Opinion; Reinitiation of Consultation on 1994-1998 operation of the Federal Columbia River Federal Power System, including the juvenile transportation program and 19 Bureau of reclamation Projects in the Columbia Basin. National Marine Fisheries Service and the National Oceanic and Atmospheric Organization.

NMFS 2000b. White paper: Salmonid travel time and survival related to flow in the Columbia River Basin. Northwest Fisheries Science Center, National Marine Fisheries Service, 2725 Montlake Boulevard East, Seattle, Washington 98112

NMFS (National Marine Fisheries Service). 2000c. Appendix D Biological effects analysis and SIMPAS model documentation. For Endangered species Act- Section 7 consultation Biological Opinion; Reinitiation of Consultation on 1994-1998 operation of the Federal Columbia River Federal Power System, including the juvenile transportation program and 19 Bureau of reclamation Projects in the Columbia Basin. National Marine Fisheries Service and the National Oceanic and Atmospheric Organization.

Northwest Power Planning Council. 1983. Columbia River Basins fish and wildlife program. Portland Oregon.

Olsen, D. and J. Richards. 1994. Inter-basin comparison study, Snake River chinook production compared to other West Coast production areas, phase II report. Pacific Northwest Project, Kennewick, Washington.

Olsen, D., J. Anderson, R. Zabel, J. Pizzimenti and K. Malone. 1998. The Columbia-Snake river flow targets/augmentation program: A white paper review with recommendations for decision makers. Pacific Northwest Project, Kennewick, Washington.

Petrosky, C. E. 1992. Analysis of flow and velocity effects: smolt survival and adult returns of wild spring and summer chinook salmon. Chinook Smolt Workshop Draft Summary. Idaho Dept. of Fish and Game, Boise, Idaho.

Petrosky, C. E., and H. Schaller. 1998. Smolt-to-adult return rate estimates of Snake River aggregate wild spring and summer chinook. Submission 10 In: Marmorek and Peters, eds. PATH Weight of Evidence Report. 6 p. + tables and figures

Raymond, H. L. 1979. Effects of dams and impoundments on migrations of juvenile chinook salmon and steelhead from the Snake River, 1966 to 1975. Transactions of the American Fisheries Society 108:505–529.

Sims, C., and F. Ossiander. 1981. Migrations of juvenile chinook salmon and steelhead in the Snake River, from 1973-1979, a research summary. Report to the U.S. Army Corps of Engineers, Contract DACW68-78-0038.

Skalski, J.R., R.L. Townsend, R.F. Donnelly, and R.W. Hilborn. 1996. Final Report: The relationship between survival of Columbia River fall chinook salmon and in-river environmental factors. Analysis of historic data for juvenile and adult salmonid production: Phase II. Bonneville Power Administration, Public Information Center, Portland, Oregon.

Smith, S. G., W. D. Muir, E. E. Hockersmith, S. Achord, M. B. Eppard, T. E. Ruehle, and J. G. Williams. 1997a. Draft: Survival estimates for the passage of juvenile salmonids through Snake River dams and reservoirs. Annual Report, 1996. US Dept. of Energy, Bonneville Power Administration, Contract Number DE-AI79-93BP10891.

Smith, S. G., W. D. Muir, E. E. Hockersmith, M. B. Eppard, and W. P. Connor. 1997b. Passage survival of natural and hatchery subyearling fall chinook salmon to Lower Granite, Little Goose, and Lower Monumental Dams. In: Williams, J.G., and T.C. Bjornn. 1995. Annual Report: Fall chinook salmon survival and supplementation studies in the Snake River reservoirs, 1995. Bonneville Power Administration, Public Information Center, Portland, Oregon.

Williams, J. G., Smith, S.G., and Muir, W.D. 2001. Survival Estimates for Downstream Migrant Yearling Juvenile Salmonids through the Snake and Columbia Rivers Hydropower System, 1966–1980 and 1993–1999. North American Journal of Fisheries Management 21(2) 310-317.

Williams, J. G. and G. M. Matthews. 1995. A review of flow and survival relationships for spring and summer chinook salmon, *Oncorhynchus tshawytscha*, from the Snake River basin. Fishery Bulletin 93:732–740.