COLUMBIA RIVER SYSTEM
OPERATION REVIEW

SCREENING ANALYSIS

VOLUME 1 DESCRIPTION AND CONCLUSIONS

AUGUST 1992

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

BONNEVILLE POWER ADMINISTRATION

CORPS OF ENGINEERS

BUREAU OF RECLAMATION

MASTER

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED *af*

This document was published for the Columbia River System Operation Review, a joint project of the U.S. Bureau of Reclamation, U.S. Army Corps of Engineers, and Bonneville Power Administration.

If you have any comments or questions, please contact:

Interagency Team
P.O. Box 2988
Portland, OR 97208-2988
Call: (503) 230-3478 (Portland), or 1-800-622-4519.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

TABLE OF CONTENTS

1	PROLOGUE	4
2	OVERVIEW OF SCREENING ANALYSIS	5
3	DESCRIPTION OF WORK GROUP SCREENING PROCESSES.....	16
3.1	POWER	18
3.2	RECREATION	26
3.3	RESIDENT FISH	37
3.4	WILDLIFE	72
3.5	IRRIGATION	95
3.6	ANADROMOUS FISH	108
3.7	FLOOD CONTROL	172
3.8	NAVIGATION	175
3.9	CULTURAL RESOURCES	181
3.10	WATER QUALITY	186
4	INSIGHTS GAINED FROM SCREENING AND PROPOSED CANDIDATE SYSTEM OPERATING STRATEGIES FOR FULL-SCALE ANALYSIS	205

CHAPTER 1

PROLOGUE

For some time each of three Federal agencies, the U.S. Army Corps of Engineers (Corps), Bureau of Reclamation (Reclamation), and Bonneville Power Administration (BPA) has recognized the increased competition and conflicting demands placed upon the water resources of the Columbia River system. Much of those resources are provided as a consequence of the development and operation of major Federal projects in the Columbia River Basin.

In the fall of 1989 the three agencies met to discuss the expiration of the Pacific Northwest Coordination Agreement and the Canadian Entitlement Allocation Agreements, and the compliance activities necessary to renew these agreements. The concept and need for a review of system operation was also discussed and an ad-hoc task group was directed to evaluate the pros and cons of such a review. In 2 months the ad-hoc group finished its work and recommended a review of Columbia River system operation be jointly conducted by the Corps, Reclamation, and BPA, with the results documented in an Environmental Impact Statement (EIS).

Approval of that recommendation in January 1990 by the three agency heads set in motion the Columbia River System Operation Review (SOR).

The first step in the SOR was to conduct a series of public scoping meetings in August 1990. Those meetings were held throughout the Columbia River Basin to understand the issues, views and concerns of the public. From an analysis of public comments made at the meetings and other input, a Scoping Document was prepared. It sets forth the purpose and scope of the SOR, identifies the issues it will address, defines how the study will be conducted, and specifies what procedures and methods will be used in carrying it out.

This report documents the screening analysis phase of the SOR. Volume 1 presents an overview of the screening analysis (Chapter 2), describes the analytical techniques used by each of 10 work groups (Chapter 3), and presents the insights learned during screening and proposes several "candidate system operating strategies" for full-scale evaluation in the next phase of analysis (Chapter 4). Volume 2 describes the 90 operating alternatives evaluated during screening and presents the various river use impacts.

OVERVIEW OF SCREENING ANALYSIS

INTRODUCTION

The SOR consists of three analytical phases leading to a Draft EIS. The first phase, Pilot Analysis, was performed for the purpose of testing the decision analysis methodology being used in the SOR. The Pilot Analysis is described later in this chapter. The second phase, Screening Analysis, examines all possible operating alternatives using a simplified analytical approach. It is described in detail in this and the next chapter. This document also presents the results of screening. The final phase, Full-Scale Analysis, will be documented in the Draft EIS and is intended to evaluate comprehensively the few, best alternatives arising from the screening analysis.

The purpose of screening is to analyze a wide variety of differing ways of operating the Columbia River system to test the reaction of the system to change. The many alternatives considered reflect the range of needs and requirements of the various river users and interests in the Columbia River Basin. While some of the alternatives might be viewed as extreme, the information gained from the analysis is useful in highlighting issues and conflicts in meeting operating objectives. Screening is also intended to develop a broad technical basis for evaluation including regional experts and to begin developing an evaluation capability for each river use that will support full-scale analysis. Finally, screening provides a logical method for examining all possible options and reaching a decision on a few alternatives worthy of full-scale analysis.

An organizational structure was developed and staffed to manage and execute the SOR, specifically during the screening phase and the upcoming full-scale analysis phase. The organization involves ten technical work groups, each representing a particular river use as listed below. Several other groups exist to oversee or support the efforts of the work groups (Figure 2-1).

Anadromous Fish

Power

Irrigation

Resident Fish

Navigation

Water Quality

Recreation

Flood Control

Cultural Resources

Wildlife

FIGURE 2-1

COLUMBIA RIVER SYSTEM OPERATION REVIEW ORGANIZATION CHART

Each technical work group will be responsible for evaluating the environmental impacts associated with the river use within their functional area. Typical steps for each group will include (1) inventory and obtain all data, (2) analyze public input, (3) review analysis methodologies, (4) review and select analytical tools, (5) plan execution of study, (6) produce interim results, (7) support public review/involvement, (8) produce final results, and (9) document findings. These functional work groups will involve participation from the public, agencies and various interest groups.

Technical specialists from each of the three lead agencies conducting the SOR staff the work groups. These groups also include individuals from other agencies and the public with expertise or knowledge in specific river uses. Particular effort was made to identify individuals and interest groups known or

believed to be involved or interested in the subject matter of one or more work groups. As the screening phase began, letters were sent inviting public and agency participation.

The Analysis Management Group (AMG) provides guidance to the work groups and represents the Federal agencies. It is composed of the SOR project and technical managers from the three lead agencies, the coordinators from each of the work groups, and representatives from the four cooperating agencies. Cooperating agencies include the U.S. Fish and Wildlife Service, the National Park Service, the U.S. Forest Service, and the National Marine Fisheries Service. The AMG developed the scope for SOR, coordinates technical studies of individual work groups, monitors progress, and evaluates the results from each work group. In this phase of the review, the AMG assimilated the work groups' screening results into a composite set of results for analysis by the lead agencies and for presentation to the public as part of the SOR public involvement program. The data contained in this document are the results of that screening phase and were compiled by the AMG.

METHODOLOGY

A formal "decision analysis" process is used to guide the analytical phases of the work groups and the SOR, in general. Decision analysis attempts to determine the sensitivity of possible decisions relative to changes in assumptions, while also accounting for uncertainty and risk. It provides a sound analytical basis upon which to make decisions and is particularly useful in revealing significant features among conflicting or competing alternatives. The decision analysis steps in screening included developing analytical approaches, identifying operating alternatives, evaluating these initial alternatives, and conducting public and agency review of the results prior to selecting a final set of alternatives for comprehensive analysis in the Draft EIS.

The initial alternatives were evaluated using a variety of "value measures" that the work groups defined for each river use. A value measure is a parameter that quantifies an effect of an operating alternative on a specific river use. Examples of value measures include: for power, annual energy produced and system power production costs; for flood control, regulated peak flow and average annual damage in dollars; for navigation, transportation costs; for wildlife, number of Canada Goose nesting sites and broods; for anadromous fish, downstream juvenile survival and travel time; for recreation, visitor hours at projects; and for cultural resources, number of historically significant sites exposed. Evaluation of the alternatives involved examining changes to or impact on these types of value measures.

To better understand decision analysis and to comprehend the screening methods and results for the SOR, the terminology pertinent to decision analysis is presented below. These terms are used throughout this document in describing the individual work group processes:

Decision factors – Those aspects of a decision which a decision maker would look to or rely upon as the basis for a decision. Decision factors can include policy issues as well as technical information.

Value measures – The key quantitative measures resulting from the technical evaluation which determines the quality of the alternative. Value measures are based on the issues and concerns raised in the scoping process and are used to assess changes or differences among alternatives.

Key variables – Variables or assumptions which have significant influence on the outcome of a given river operation. Initially, variables are identified using professional judgment. These are confirmed through the use of sensitivity analysis. If a key variable is changed, the resultant value measure calculated is changed.

Uncertainty – Most, if not all, of the variables considered in the screening analysis are imperfectly defined or known. Also, for many, there may be little or no agreement among interested parties as to what

values should be used. This situation is dealt with using probabilistic analysis. Maximum and minimum values of the variables are established using known or assumed ranges based upon professional judgment of experts in the particular field. Sensitivity and probabilistic analyses will take these ranges into account when computations are made.

Influence diagrams – A graphic display of the important variables, factors and cause-effect relationships identified by a work group to portray how the value measures are affected. An example of an influence diagram is shown in Figure 2-2.

Screening models – Computer models written in commercial spreadsheet software such as Excel or Lotus. The models characterize the relationships between key variables which experts believe reasonably define the physical effect of a given river operation. These models were individually developed or

adapted by the work groups. Key variables are entered into algorithms which compute value measures for each river use.

Sensitivity testing – One of two parts of the Supertree software package. It is used to test the sensitivity of a value measure to changes in each of the input variables. The software executes the screening model throughout the range of the variables and prepares the results in the form of a “Tornado” diagram. Each variable is set at its minimum and maximum value to determine its effect on the resulting value measures, thereby showing its sensitivity.

Tornado diagram – Graphical result of the sensitivity testing. It displays the range of results for a particular value measure for each variable used in the screening model. This information is presented with the variable having the largest effect on the value measure on top and all others in decreasing order of significance. Graphically, this appears in the shape of a tornado. Variables with the largest effect on the value measure represent the key uncertainties and are selected for the subsequent probability analysis. An example of a tornado diagram is shown in Figure 2-3.

FIGURE 2-3

EXAMPLE - TORNADO DIAGRAM FOR ANADROMOUS FISH

Decision tree – A chart that shows all possible combinations of outcomes for a particular decision. It includes both choices that a decision maker can make and variables which have some range of uncertainty. These uncertain variables are assigned probabilities of occurrence. An example is shown in Figure 2-4.

FIGURE 2-4

EXAMPLE - DECISION TREE FOR ANADROMOUS FISH

Probabilistic analysis – A series of repeated analyses using the screening model to calculate each individual branch of a decision tree for one possible alternative. Each branch involves a particular combination of variables and choices and is assigned a probability of occurrence. The branches also represent all of the possible outcomes. Full enumeration of an alternative involves repeated running of the screening models to calculate the value measure for every combination of input variables. The results are used to prepare a cumulative probability distribution curve depicting probabilistic results for each

value measure. This calculation is performed by the second part of the Supertree software. An example is shown in Figure 2-5.

FIGURE 2-5

EXAMPLE - CUMULATIVE PROBABILITY DISTRIBUTION FOR ANADROMOUS FISH

Supertree software – Commercial software used to complete the sensitivity analysis on each screening model and the probabilistic analysis for each alternative. Supertree automatically links to the screening models, stores the results of each run of the model, and computes a cumulative probability distribution curve for the alternative. It can graphically compare results to a previously computed base case or another alternative. Deviation from the base case or another alternative is readily observed across the range of probabilities by inspection of the graph.

Risk – The chance or consequences of making the wrong decision. Risk is assessed by assigning probabilities to the various choices represented by the branches of the tree structure used in the screening process for each alternative. These probabilities are also reflected in the computed results and the cumulative probability distribution curve.

Accuracy – A measure of the ability to predict an outcome or result. Screening models are not intended to be a complete or detailed representation of the river uses. They are intended to characterize the general nature of the processes being evaluated. They are used for assessing a large number of alternatives and, most importantly, for testing the response of the river system to those alternatives. Models are capable of showing differences but are not reliable predictors of absolute values of impacts. Much can be learned from this type of analysis about what factors really make a difference in system operation. An increased level of accuracy is expected when large scale models are used in the full-scale analysis.

Reliability – A measure of repeatability or reoccurrence. During screening much of the reliability of the analysis is dependent upon the professional judgment brought to the table by experts in each of the river use areas within the work group process. Work groups identified and have initiated additional information and data gathering for use in full-scale analysis, which should provide a greater level of accuracy and reliability.

PILOT ANALYSIS

Prior to initiating the screening phase and during the development of the scoping document, a "pilot analysis" process was tested by the SOR team, specifically four initial work groups. The purpose of the pilot analysis was to become familiar with the decision analysis process, to learn the operation of the Supertree software, and to test the analytical method from start to finish using three operating alternatives. Anadromous Fish, Resident Fish and Wildlife, Recreation, and Power Work Groups were created and involved in this test. Work groups members included staff from the three lead Federal agencies only.

During this phase, these work groups proceeded through all of the steps of the decision analysis process. They prepared influence diagrams, developed a simplified screening model, identified alternatives, evaluated sensitivity, determined key variables, assigned ranges of uncertainty and probabilities, calculated value measure results, appraised results, and developed conclusions. This phase was accomplished in a 6-month period from November 1990 to April 1991. The level of detail was confined to that which would approximate and illustrate the problem solution and methods to be used in screening.

Results of the pilot analysis were documented in separate Pilot Analysis Reports by each work group. These reports also served as an introduction to the next phase of the study, the screening analysis. These reports were useful to the new work groups formed for the rest of the study and to the agencies and public invited to participate in the screening phase of the study.

SCREENING ANALYSIS

The screening analysis process began by expanding the number of work groups from four to ten, one for each river use listed above and inviting participants from the region to join in the technical analysis. The Resident Fish and Wildlife Work Group, which was one group during the Pilot Analysis, was split into two groups for screening because of the clear differences in focus.

The purpose of the work groups was to provide a forum for experts and other interested parties to work together on a common river use. It was anticipated that work group members would share ideas and information as well as attempt to reach a consensus on technical issues. Where that was found difficult, it was hoped that the members would gain an understanding of others' viewpoints on technical

matters. The idea was to bring the best available science to the table for all to examine and consider in developing analytical approaches and operating strategies for SOR.

Membership on each work group was established by written invitation from the SOR project management team. A list of potential members was drawn up by the team and letters of invitation were sent. Notification of work group formation was also announced in the SOR newsletter, "Streamline". Others interested in participation were welcome to join a work group.

The interest groups and public were given the flexibility to participate at two levels, which were referred to as tier 1 and tier 2. Tier 1 participation involved representatives from outside of the three agency team who indicated a desire to have direct and active involvement in work group meetings. Tier 2 participation included those who wished to be kept informed of work group activities but could not or did not desire to attend all meetings.

An initial assignment was given to each work group at the beginning of the screening phase. This assignment included a request to identify operating alternatives, to develop screening methodologies and models, to identify information and data needs for full-scale analysis, and to make recommendations to project management on ways to fund and obtain the necessary information and data. Assignments made later in screening included documentation of each work group's process and results. A record of activities and accomplishments is contained in the minutes of each work group meeting.

Within each work group, the screening process began with meetings designed to help members identify important factors and physical relationships for their particular river use. Each of the ten work groups place different values on the river system depending upon what they seek from the system. For them the decision basis depends upon the factors they value most highly. Each work group sought to identify a single or at most two or three value measures which best characterize or measure an operating alternative's effect on their interests.

Each work group prepared an influence diagram to graphically display the variables and their relationships to the desired result. From the influence diagram, key variables were identified for use in the screening model. Next, the spreadsheet computer models or similar models were prepared, developed and tested. These models use the key variables as inputs and calculate appropriate value measures. Then, each work group performed a sensitivity analysis and displayed the results graphically in the form of a "tornado" diagram. From the sensitivity analysis, work groups identified the variables that have the most influence over the value measures and represent significant uncertainty. These variables are allowed to range within the screening model whereas less significant variables are held constant at a median or average level. Sensitivity analysis verifies that the less significant variables do not affect the calculated value measure results.

The next significant step in the screening process involved identifying and describing operating alternatives for analysis. Most of the alternatives were developed by members of the work groups or by the AMG. However, in some cases, the idea for an alternative came from an outside source such as the public scoping meetings, other agencies, the Salmon Summit, or regional organizations such as the Northwest Power Planning Council, Pacific Northwest Utilities Conference Committee, and Columbia Basin Fish and Wildlife Authority. The originator of each alternative prepared a one-page description of the alternative. The description not only described the intent of the alternative but also outlined the parameters and limitations under which the system would operate.

The work groups were specifically instructed to define alternatives that would be most beneficial to their particular river use as well as those which would be less ideal but provide an acceptable level of benefit. It was recognized that single use alternatives would have limited value when a system operating

strategy (SOS) is put together later. However, such alternatives were viewed as being valuable in testing the response of the system to change and in identifying limiting conditions of the system or of river uses.

The analysis of alternatives required the capability to determine what the river system would physically do or look like under any given operating alternative. The means to do this were provided by existing large scale computer models which simulate the physical operation of the river. In the Columbia River Basin, two physical models are used by the Federal agencies, the Corps of Engineer's Hydro System Seasonal Regulation (HYSSR) and BPA's Hydro Simulation (Hydrosim). The team decided that the hydroregulation effort should be shared between BPA and the Corps because of the large number of alternatives being analyzed and because the Corps had already completed work for the 1992 Options EIS. The ability to compare results of the studies for general consistency was an additional benefit.

The hydroregulation models simulate a 50-year period. However, to simplify the screening analysis, five water years were selected to represent the range in hydrologic conditions in the Columbia River Basin. The specific years were chosen after reviewing the 50-year period of record and dividing it into five bands from dry to wet years. The years chosen for modeling are shown below:

Flow Conditions	Year	Probability of Occurrence Assigned for Screening
Low	1930-31	6%
Medium low	1939-40	18%
Medium	1937-38	50%
Medium high	1956-57	18%
High	1955-56	8%

HYSSR studies made by the Corps are all done on a continuous basis using a full 50 years of historical record. Continuous means the results of first year are used as the starting point for the subsequent year throughout the 50-year run. Runs made with BPA's Hydrosim model were done for five single years, one year at a time. The full fifty years of record were not analyzed. Since information for the previous year was not determined, an assumed starting elevation for each reservoir was necessary. Average conditions for July were used as the starting point for each of the 5 years.

Use of single years for the Hydrosim analysis, beginning in July and ending in June, posed a special problem for biologically-oriented work groups. Reservoir flow and elevation information ending in June did not allow the work groups to assess the impact of that year's operation into the fall season, which is important to many fish and animal species. This problem was corrected by extending the simulations into the next year by adding an additional 8 months of information. HYSSR studies, being continuous, did not require this procedure as the data was readily available for the beginning of the next year.

Alternative descriptions were forwarded to the River Operation Simulation Experts (ROSE) Group. Each alternative was given an abbreviated name and a number. The first three letters in the abbreviated name indicate which work group or other group initially identified the alternative. Abbreviations used in the name are shown on the first page of Volume 2. ROSE also assigned each alternative to either the Corps or BPA hydroregulators. The alternative was readied for modeling by making appropriate adjustments to one of the two hydroregulation models. The hydroregulators operated the appropriate models to determine project and river flows, reservoir elevations, spill amounts, and power generation on a monthly basis. Model runs for each alternative took anywhere from a few days to a week or more

to complete, depending upon the operating complexity of the alternative. Results were checked for errors and inconsistencies, and rerun if necessary.

The hydroregulators began by defining a base case operation. The base case represented the operating strategy that occurred in 1990-91. Both BPA and the Corps simulated this operation with their respective hydroregulation models and produced what became the first two alternatives in the list of 90 alternatives screened (AMG-BBPA and AMG-BCOE). They are important because all subsequent alternatives were compared to one of these base cases. If an alternative was simulated using Hydrosim, the work groups' impact results were compared to the impact results obtained for the BPA base case. Likewise, if an alternative was simulated using HYSSR, the results were compared to the Corps base case results. The results of the BPA base case were slightly but not significantly different from the results of the Corps base case.

When satisfactory hydroregulation results were obtained for the various alternatives, the model output was distributed to each of the work groups. The work groups entered the flows, elevations, and other data as appropriate into their screening models for calculation of their respective value measures. Any errors or inconsistencies noted by work groups were brought to the attention of ROSE or AMG for discussion and resolution. Further reruns by ROSE or the work groups were sometimes necessary to assure that the intended objective of the particular alternative was met. If the alternative's objective could not be met, then that finding was noted.

Value measure results were reported by work groups to the AMG for compilation, evaluation, and incorporation into this document. Each work group reported three results for each value measure for each alternative—an expected value, a 10 percent value and a 90 percent value. The expected value is the primary numerical result from the screening analysis and represents the probability-weighted average for all branches of the decision tree represented by the work group's model. It is the probability of each branch multiplied by the result of that branch summed together. For example, if the decision tree had only two branches and the probability of occurrence for each branch was 50 percent, then the expected value is simply 0.5 times the two results added together, or simply the average of the two results. The 10 and 90 percent values are derived from the cumulative probability distribution curve which plots the results of each branch of the decision tree and its respective probability in a cumulative fashion. The 10 and 90 percent values represent the uncertainty associated with the expected value. They establish the likelihood (e.g., 10 percent) that the value measure result would be less than or equal to that value. By comparing the expected value of the alternative to the appropriate base case value, the impact of the alternative can be readily assessed. Likewise, the 10 and 90 percent values can be compared and assessed.

Each work group generally followed the screening process as it is described above. However, differences did occur which are unique to the various groups. Consequently, each work group was asked to describe the specific details of the screening process they followed and to incorporate the actual variables, uncertainties, and other information used in these descriptions. The next chapter presents these descriptions.

CHAPTER 3

DESCRIPTION OF WORK GROUP SCREENING PROCESS

For screening, the 10 work groups were responsible for evaluating the effects of 90 alternative Columbia River system operations. This chapter describes the details of the work group screening process. More specifically, each of the work groups prepared an explanation of their specific screening methodologies and techniques, including information on key input variables, data, river use relationships and impact algorithms, decisions made during screening and in some cases general conclusions of screening. The work groups included information believed to be the most significant to their individual efforts. Many groups chose to provide additional detail on specific issues and conclusions of screening.

This chapter is divided into 10 sections. While each section represents one work group's description of screening, they were prepared separately. As reprinted together here, there is some duplication and inconsistency regarding the coverage of the screening process. Although, each section is intended to identify the key elements of individual work group screening processes, they may not provide the entire story for that process. In some cases, work groups added additional information relating to the upcoming full-scale analysis. Questions regarding specific issues or procedures should be directed to the work group. The content of these descriptions are summarized below.

3.1 Power. The Power Work Group is responsible for analyzing the effects of changes in Columbia River system operations on the ability of the Northwest regional power system to serve regional loads and the costs of serving that load. The Power screening description provides information on the screening model, contains a general framework and background section, describes model input and output parameters, discusses the analytical results from the model, and concludes by outlining effects not considered in the screening process.

3.2 Recreation. The Recreation Work Group is responsible for analyzing the effects of changes in Columbia River system operations on outdoor recreational opportunities. The Recreation screening description provides information on the public issues and conceptual framework leading to the screening model, describes the scope of the modeling, presents model assumptions and methodological procedures, and discusses the sensitivity analyses and their results.

3.3 Resident Fish. The Resident Fish Work Group is responsible for analyzing the effects of changes in Columbia River system operations on resident fish populations and associated habitats both in the reservoirs and in downstream river reaches. The Resident Fish screening description provides information on the screening technique, discusses the screening models, describes model assessments, discusses the sensitivity and probabilistic analyses, and provides several appendices which provide information used in developing screening models.

3.4 Wildlife. The Wildlife Work Group is responsible for analyzing the effects of changes in Columbia River system operations on wildlife populations and their associated habitats. The Wildlife screening description provides information on the public issues and conceptual framework which led to the development of screening models, presents model assumptions and methodological procedures, and discusses sensitivity and probabilistic analyses.

3.5 Irrigation. The Irrigation Work Group is responsible for analyzing the effects of changes in Columbia River system operations on irrigation and municipal water interests. The Irrigation screening description provides information on the scope of irrigation analysis, discusses model assumptions and methodological procedures, and presents a brief summary of the screening results and groups alternatives by their impacts.

3.6 Anadromous Fish. The Anadromous Fish Work Group is responsible for analyzing the effects of changes in Columbia River system operations on the anadromous fishery resource. The Anadromous Fish screening description provides information on the value measures selected for analysis and the application of two different screening models, describes modeling input, uncertainties and sensitivities, and discusses model assumptions, methodological procedures, and model results. Several appendices on the modeling techniques are included.

3.7 Flood Control. The Flood Control Work Group is responsible for analyzing the effects of changes in Columbia River system operations on both system and local flood control capabilities. The Flood Control screening description provides information on the screening model, presents assumptions used in modeling, identifies damage centers, and discusses methodological procedures.

3.8 Navigation. The Navigation Work Group is responsible for analyzing the effects of changes in Columbia River system operations on navigation and transportation capabilities. The Navigation screening description provides information on the model and key assumptions, and provides qualitative conclusions on the results of screening.

3.9 Cultural Resources. The Cultural Resource Work Group is responsible for analyzing the effects of changes in Columbia River system operations on cultural resources, specifically archaeological and historic sites bordering the river and the reservoirs. The Cultural Resource screening description provides information on model assumptions, screening results, and general conclusions.

3.10 Water Quality. The Water Quality Work Group is responsible for analyzing the effects of changes in Columbia River system operations on water quality, specifically water temperature and dissolved gases. The Water Quality screening description provides information on model assumptions and parameters, identifies value measured used, discusses screening model selection, describes simulation procedures, discusses model uncertainties, and provides general qualitative conclusions.

SECTION 3.1

POWER WORK GROUP SCREENING PROCESS

INTRODUCTION

This document discusses the work performed by the System Operation Review (SOR) Power Work Group during the screening phase of the SOR analysis. The Power Work Group is responsible for analyzing the effects of changes in Columbia River system operations on the ability of the Northwest regional power system to serve regional loads and the costs of serving that load. The Northwest regional power system consists of Federal and non-Federal hydropower projects on the mainstem of the Columbia and Snake Rivers, numerous smaller hydro projects on other river reaches, and a number of thermal plants (coal, nuclear, and combustion turbines).

The screening analysis was a simplified version of the subsequent full-scale analysis phase that will analyze the power system impacts of alternatives in detail. The screening analysis had two steps. The first consisted of developing a spreadsheet model to calculate quickly changes in system costs given changes in the operation of the river system. The second consisted of using this model to show the differences, under conditions of uncertainty, among the numerous system operating strategies that were developed for screening.

DESCRIPTION OF THE SCREENING MODEL

The power screening model was designed to calculate the total system costs of a given operation of the power system. To do this, it relies on a number of simplifying assumptions with respect to resource acquisition, resource dispatch, costing, etc. The advantage of this simplification is the ability to assess quickly a wide range of inputs and thereby deal with uncertainty and its impacts on power system costs. The disadvantage of this simplification relates to the model's usefulness. The model is primarily useful for ranking alternatives; it is less useful for predicting exactly the magnitude of change in power system costs given a particular system operating strategy.

GENERAL FRAMEWORK

Model inputs consist of information on total generation from the existing hydro and thermal system, loads, new resource costs, etc. Using these inputs, the model determines monthly loads, acquires new resources, and operates the system by displacing regional thermal plants and selling excess power outside the region. The output of the model is the total annual cost for the entire Pacific Northwest power system in millions of 1990 dollars. This cost consists of new resource capital costs plus operating costs for all resources, less revenues from extra regional sales.

The model currently runs an individual year, with a monthly time step. The model splits the months of April and August into two parts, as is commonly done in hydrologic models. It is possible to run any year between 1992 and 2011. For screening, the year 1992 was selected.

DETERMINATION OF USABLE HYDRO ENERGY PRODUCTION

One of the most important inputs needed by the power screening model is total hydrosystem generation by month. The model has this information for both the base case and for each alternative for each water condition (see hydroregulation model discussion for details on development of this information). In detailed hydrosystem modeling, this information would be used in a critical period analysis to determine the amount of firm energy load carrying capability (FELCC) the hydrosystem could produce. The FELCC would be calculated for both the base case and the alternative; the difference would show how an alternative had either increased or decreased the hydrosystem's FELCC.

The simplified nature of the screening analysis and the number of alternatives analyzed precluded this type of detailed analysis. Therefore a simplified method for calculating a proxy for an alternative's FELCC was necessary. The screening model compares an alternative's monthly hydro generation in the 1930-1931 water year with the base case's monthly hydro generation in that water year. For each month, the smallest of these two numbers is selected. This is the amount of hydro generation that can be used (usable hydro energy) to meet Northwest load obligations given this alternative. The average of this string of monthly numbers is the alternative's yearly usable hydro energy production. Total hydrosystem generation by month minus monthly usable hydro energy gives the alternative's non-firm hydro generation for each month for each water condition.

By comparing an alternative's yearly usable hydro energy production with total 1930-1931 hydro generation in the base case, a proxy for the change in FELCC due to an alternative is obtained. This is a very rough approximation of the change in FELCC that would be obtained given traditional critical period analysis. This number is used to calculate the change in system costs only under Case 1 (see below).

NEW RESOURCE ACQUISITION PHILOSOPHY

One of the more difficult questions in determining power system costs is determining the amount of resources needed to meet load growth or to replace losses in the existing system's capability. This question is especially difficult given the wide range of system operating strategies examined in this screening analysis. Traditional resource planning methods have relied on the hydrosystem's flexibility to shape new resources into the power system. In other words, resource needs could be determined on an "average annual" basis, and the hydrosystem could be counted on to "fill in" monthly deficits resulting from the fact that the new resource's shape did not exactly match the system's needs.

These traditional methods are called into question under many of the alternatives analyzed here. The hydrosystem's flexibility is often severely restricted by the constraints imposed by many of these alternatives. The ability to cover monthly deficits given acquisitions that replace average annual deficits may no longer be possible. Hence, the screening model assumes that the hydrosystem cannot shape to cover monthly deficits. Given this assumption, the model incorporates three different philosophies with respect to resource acquisitions, referred to as Cases 1, 2, and 3. They are as follows:

Case 1. The system's annual load resource balance is calculated using the alternative's yearly usable hydro energy production, resulting in an average annual deficit or surplus. If a deficit results, it is covered by acquiring base load resources. These resources run at all times (are not displaceable), and 100 percent of their costs must always be paid. Examples of this type of resource might be conservation, nuclear plants, non-dispatchable cogeneration, run-of-river small hydro. The power system does not control the scheduling of these resources.

The difference between the average annual deficit and the worst monthly deficit (calculated using an alternative's monthly usable hydro energy production) is covered by acquiring a low capital cost, high operating cost resource (like combustion turbines). This resource is operated only when there is insufficient non-firm energy to cover the monthly deficit.

Case 2. The system's worst monthly deficit is calculated (again, using an alternative's monthly usable hydro energy production). This deficit is covered by adding low capital cost, high operating cost resources to the system. These resources are often displaced if there is excess hydro, thereby saving the resource's operating cost but still having to incur the resource's capital cost. An example of this type of resource is a combustion turbine.

Case 3. No resources are acquired. The system buys energy on the purchase market if it is deficit and sells energy into the non-firm market if it is surplus. This is calculated on a monthly basis.

MODEL INPUTS

The model inputs are described below.

Existing Hydro System. As described above, this is specified as an amount of usable hydro energy production to be provided in each month. Non-firm hydro by month is also an input. The price at which non-firm can be sold is also specified. This price is expressed as a demand curve in blocks of 1000 average megawatts (aMW), with prices falling as the amount of non-firm sold increases.

Existing Thermal Resources. The size of the existing thermal system is specified. This is divided into low cost thermal and high cost thermal, based on operating costs. All resources other than thermal plants (cogeneration, small hydro, imports, etc.) are included in the low cost thermal category. Operating costs for each category of thermal are also provided.

Loads. A yearly total regional system load is specified, along with a monthly load shape. The top quartile of the direct service industries' load is also specified. The model has an input table showing loads for each year from 1992 through 2011 (1992 has been chosen for screening).

New Resource Costs. For Case 1, the total cost of the new resource is specified. For Case 2, the total capital cost of the new resource is specified, with the operating cost assumed equal to the operating cost of the existing high cost thermal resources. For Case 3, a purchase price is specified, which will only be incurred when a purchase is actually made. This price is defined as a supply curve in blocks of 1000 aMW, with prices increasing as the quantity purchased increases.

Top Quartile Cost. This input is necessary to value the cost to the direct service industries from having their top quartile load interrupted. This may be thought of as the cost of replacement power, the cost of shutting down manufacturing, etc. It is set equal to the operating cost of high cost thermal resources.

Intertie Limit. The size of the Intertie over which non-firm is sold is specified.

Maintenance For Low Cost Thermal. A thermal maintenance schedule for all low cost thermal plants is specified. This schedule is monthly and shows what fraction of the yearly average energy provided by low cost thermal is available in each month.

MODEL OUTPUT

The model output consists of the total annual system cost for the entire Pacific Northwest power system in millions of 1990 dollars. This cost is calculated for each alternative for each different resource acquisition philosophy — Cases 1, 2, and 3. The yearly usable hydro energy production in aMW for each alternative is also determined.

INPUT UNCERTAINTY

A number of inputs specified in the model are uncertain — we cannot predict with certainty what their values might be. A sensitivity analysis was performed to determine which inputs affect annual system costs most significantly. In other words, if we vary the uncertain inputs from their low to high values, how much change do we get in the annual system costs? Which inputs cause this change to be the greatest? In the sensitivity analysis, only one input is varied at a time; the inputs not being varied remain at their medium case values.

The sensitivity analysis was used to determine which input variables should be treated as uncertain. On the basis of this analysis, uncertainty is reflected in monthly non-firm hydro amounts, loads, fuel prices, non-firm prices, and new resource costs.

The amount of non-firm hydro available monthly is uncertain and depends on weather conditions. For the screening analysis, five historic water conditions have been selected: 1931, low water; 1940, medium-low water; 1938, medium, or average water; 1957, medium-high water; and 1956, high water. The model calculates results based on these five water conditions.

For the other uncertain inputs, three values (or streams of values) are estimated: a medium, or most likely value, a high value and a low value. In addition, the probability associated with the likelihood of each value is also estimated.

Several examples may provide an illustration. Future loads are uncertain. The model has values for low, medium, and high load forecasts, along with the probabilities associated with their occurrence.

Future fuel prices are also uncertain. Although there is not a specific input called "fuel price" in the model, a number of inputs are directly or indirectly influenced by future fuel prices. These include high and low cost thermal operating costs, the cost of not serving top quartile load, the yearly non-firm price and the yearly purchase price. Each of these inputs has a value associated with the medium, or most likely fuel price forecast, a high forecast, and a low forecast.

Other inputs are deterministic — we know their values with reasonable certainty. These inputs include the size of the existing thermal system, the size of the Intertie, thermal maintenance schedule, etc.

Input ranges and associated probabilities for some uncertain inputs are shown on Table 3-1.

OTHER ASSUMPTIONS

A number of additional assumptions have been incorporated into the model. They are:

Firm surplus is sold as non-firm. No attempt is made to sell it at a higher price.

All low cost existing thermal is "must run," except when on maintenance.

No real escalation is assumed.

Analysis is conducted in real, 1990 dollars.

TABLE 3-1
INPUT VALUES

FUEL PRICE FORECAST		LOW	MED	HIGH
PROBABILITY		20%	55%	25%
			(mills/kwh)	
TOP QUARTILE COST		20	30	40
OPERATING COST - HIGH		20	30	40
OPERATING COST - LOW		5	15	25
			(mills/kwh)	
PURCHASE PRICE - CASE 3	0	25	35	45
(average MW)	1000	30	40	50
	2000	35	45	55
	3000	40	50	60
	4000	100	150	200
	5000	100	150	200
	6000	100	150	200
	7000	100	150	200
	8000	100	150	200
	9000	100	150	200
	10000	100	150	200
	11000	100	150	200
	12000	100	150	200
	13000	100	150	200
	14000	100	150	200
	15000	100	150	200
NEW RESOURCE COSTS				
PROBABILITY		15%	60%	25%
			(mills/kwh)	
TOTAL COST - CASE 1		20	35	70
CAPITAL COST - CASE 2		2	7	10
LOADS				
PROBABILITY		20%	60%	20%
			(avg MW)	
1992 LOAD		18140	20020	21470
2001 LOAD		17825	21910	26420
2011 LOAD		17475	24010	31920

TABLE 3-1 (continued)

NONFIRM PRICE

PROBABILITY		LOW FUEL PRICES			MEDIUM FUEL PRICES			HIGH FUEL PRICES		
		25%	50% (mills/kwh)	25%	25%	50% (mills/kwh)	25%	25%	50% (mills/kwh)	25%
(average MW)	0	7	11	15	14	21	28	20	32	40
	1000	6	10	14	11	18	25	17	29	37
	2000	5	10	13	8	15	22	15	26	34
	3000	4	9	12	5	12	19	12	23	31
	4000	3	8	11	4	11	18	9	20	28
	5000	3	8	8	3	10	17	6	17	25
	6000	0	0	0	0	0	0	0	0	0
	7000	0	0	0	0	0	0	0	0	0
	8000	0	0	0	0	0	0	0	0	0
	9000	0	0	0	0	0	0	0	0	0
	10000	0	0	0	0	0	0	0	0	0
	11000	0	0	0	0	0	0	0	0	0
	12000	0	0	0	0	0	0	0	0	0
	13000	0	0	0	0	0	0	0	0	0
	14000	0	0	0	0	0	0	0	0	0
	15000	0	0	0	0	0	0	0	0	0

ANALYTICAL RESULTS FROM SCREENING MODEL

By using the probabilities and input ranges specified above, the expected value of the annual system cost of each of the alternatives under conditions of uncertainty can be calculated. The decision analysis "tree" is shown in Figure 3-1.

For each branch of the tree, the screening model is used to calculate the annual system cost. Each branch represents one set of values for the inputs which are uncertain. For example, one branch of the tree would calculate the annual system cost assuming all the uncertain inputs at their low values (the top branch shown in Figure 3-1); another might assume half the inputs at their low values, the other half at high, etc. All uncertain inputs are varied from their low to high ranges on the decision tree and an annual system cost is calculated for every combination. By multiplying the annual system cost for each branch of the tree by the associated probabilities and adding these results, an expected value for the entire tree is calculated.

The results of the analysis for each alternative are shown in Volume 2. To evaluate the effect a particular alternative has on power system costs, the specific value measure to be used is the increase in the expected value of system costs for a particular alternative as compared to the base case. This is calculated for each resource acquisition philosophy, Cases 1, 2, and 3. In situations where the alternative reduces system costs, the value measure is negative. The loss in yearly usable hydro energy production

FIGURE 3-1

DECISION ANALYSIS TREE

Petno/Core/DECISION.CDR
5/15/92/RPS/jp

for 1931 is also calculated. This gives a total of four value measures for each alternative. These value measures are shown, by alternative, in Volume 2.

Along with the expected value results in Volume 2, 10-90 percent values are described. The 10-90 percent values are derived from a cumulative probability distribution. The cumulative probability distribution gives the likelihood (e.g., 10 percent) that the annual system cost will be less than or equal to some amount (the value at that point).

OBSERVATIONS AND COMMENTS

The quantitative results developed from the screening model and presented in Volume 2 analyze the effects of changes in Columbia River system operations on the ability of the Northwest regional power

system to serve regional energy loads. However, the Northwest regional power system also delivers another product—capacity. The limited scope of the screening analysis prevented a rigorous treatment of the effects of changes in river operations on the ability to deliver capacity. However, for screening purposes, a qualitative estimate of capacity impacts was possible.

The capacity impacts for each alternative in Volume 2 are described in each alternative's observations and comments section under Power. The capacity considered is sustained peaking capacity, which is the ability of the Columbia River power system to deliver additional energy on a given number of heavy load hours (for example 50 hours) each week, and to enable the return of an equal amount of energy on light load hours.

Capacity impacts were classified into three broad ranges: minor—loss of 1000 megawatts (MW) or less; major—loss of 1000 to 4000 MW; and extreme—loss of 4000 MW or more. These are subjective classifications based on an interpretation of what each alternative required. For a few alternatives, more precise numbers were available and they are shown. In several alternatives, it was unclear how restrictive a requirement was. For example, does a requirement to operate to flood control rule curves require that each day and each hour the reservoir be at these levels, or is there some flexibility, and if so, how much? If it was not clear, normally no flexibility was assumed.

The estimates are based on the effects on reservoir and run-of-river plant operations. The major impacts come from three effects: requiring a forebay operation that does not allow shaping of water to meet the daily load shapes, requiring an outflow that does not allow shaping, or drafting the reservoirs so heavily that they are empty and unable to provide water when it is needed.

There are other "capacity" effects that are not considered here:

1. The ability to control the generation to meet the load for each company's load control area on a moment-to-moment basis.
2. The ability to shape the amount of energy produced by each company to meet its load shape and firm contracts in a time frame that is less than a full month. This is important for Pacific Northwest Coordination Agreement Coordinated System operations.

These considerations will need to be revisited during the full-scale analysis of alternatives.

SECTION 3.2

RECREATION PILOT MODEL SCREENING PROCESS

INTRODUCTION

The System Operation Review (SOR) Recreation Work Group (RWG) was formed to analyze and evaluate how outdoor recreation opportunities provided in the Columbia Basin may be affected by changes in system operating strategies. During full-scale analysis, the RWG will focus on five Federal storage projects — Hungry Horse, Libby, Albeni Falls, Grand Coulee, and Dworshak — and nine downstream run-of-river projects — Chief Joseph, Lower Granite, Little Goose, Lower Monumental, Ice Harbor, McNary, John Day, The Dalles, and Bonneville. In addition, the RWG will analyze those system operating strategies directly affecting recreation resources downstream of Federal hydro projects. These free flowing river stretches include the Columbia River below Grand Coulee and Bonneville, Clearwater River below Dworshak, Pend Oreille River below Albeni Falls, Kootenai River below Libby, and Flathead River below Hungry Horse.

Outdoor recreation is only one of the interrelated and competing uses of the river system potentially affected by changes in Columbia River system operations. In addition to recreation, the multiple uses of the river system include power production, flood control, irrigation, navigation, water supply, salmon and steelhead migration, and resident fish and wildlife habitat. Recreation is an extremely important use of the Columbia River, providing innumerable forms of leisure activities for Pacific Northwest residents and tourists. Fishing, boating, hunting, camping, and swimming are some of the diverse outdoor recreation opportunities available at the 14 Federal projects encompassed by SOR. Any change in system operations will affect the quantity and quality of recreational activities available to the public through fluctuations in reservoir elevations and in-river flows.

The RWG accomplished the screening analysis process in three phases: model development, sensitivity testing, and alternative screening analyses. In the first modeling stage, the RWG developed first-cut “pilot” simulation models (models) that provided an analytical tool capable of quantitatively estimating how recreation resources are affected by changes in system operations. These models are simplified versions of the technical method that will be developed to analyze the quantitative impacts on Columbia River recreation resources in full-scale analysis. Although preliminary in nature, the models serve as good proxies to estimate the range of recreation impacts likely to occur by altering the Federal hydrosystem. Consequently, the RWG applied these models to quantify recreation impacts during the alternative screening phase of SOR.

In the second phase, the recreation models were evaluated using the Supertree software program. Sensitivity analysis explained which variables driving the recreation models (i.e., changes in elevations) were most important in explaining how the quantitative measure of recreation impacts changes with changes in hydro alternatives. Key input variables for each model were identified before screening was conducted in order to facilitate the screening process. Phase three involved screening dozens of hydro alternatives through each of the recreation models and generating a quantitative measure of recreation impacts using the Supertree software.

The public issues, conceptual framework, analytical scope, assumptions, and methodological procedures used to develop the RWG’s recreation models are described in detail in the following

sections. The Sensitivity Analyses section presents the results of the key input parameters that forms the structure of the recreation screening models.

PUBLIC ISSUES

The SOR public scoping process identified several issues pertaining to the effects of hydropower system operations on the quantity and quality of outdoor recreation resources available at Columbia River project sites. The RWG recognized that any modeling effort needed to adequately capture and reflect the concerns of the public. This was intuitively obvious because outdoor recreation is extremely important to local economies and the overall quality of life in the Pacific Northwest.

Most of the public issues concerned the deleterious effect of water releases and consequent drawdowns during peak recreation seasons. Severe reservoir drawdowns render boat launching ramps and marina facilities unusable, eliminate shore access, and diminish aesthetic qualities. Water releases affect the quality of recreation experiences in those river reaches that provide suitable flows for stream fishing and white-water boating and floating activities. Moreover, radical changes in system operations can disrupt popular recreation activities that are typically not as sensitive to normal operating conditions, such as wind surfing in the Columbia River Gorge National Scenic Area. Thus, the recreation public is concerned about the systemwide effects of changes in Federal projects and their impact on outdoor recreation opportunities throughout the Columbia River Basin.

CONCEPTUAL FRAMEWORK

The RWG developed a comprehensive conceptual framework that demonstrated the linkages between the primary inputs and outputs of the recreation models (Figure 3-2). This influence diagram shows the relationship between the physical parameters of the system, the different forms of recreation activities available to participants, and resultant effect to be measured. The conceptual model is driven by reservoir lake elevations and streamflows. Fluctuations in lake hydrology and flows alter the suitability of recreational opportunities in terms of access, aesthetics, safety, and water quality. Changes in hydrologic conditions impact the productivity of biological resources in fluvial and lacustrine systems. The abundance and distribution of fish and wildlife populations vary in direct response to changes in these biological trophic relationships. The quality and quantity of recreational seasons for such activities as fishing, boating, and camping, are directly influenced by variations in resource abundance and system hydrologic conditions. Such impacts on recreation are measured as a change in the quantity of recreation participation rates, expressed as visitor-days or visitor-hours. If desired, the final measure of impacts can also be translated into monetary terms to quantify the value of Columbia River Basin recreation activities for the purposes of benefit-cost analysis.

ANALYTICAL SCOPE

The recreation models developed for screening focused on four Federal projects which were thought to best characterize the kinds of recreation impacts that could be expected by altering the system. The RWG determined that it was not necessary to develop models for every Federal project to satisfy the requirements of screening analysis. Rather, models developed for a representative subset of components of the system facilitated analysis of the 90 alternatives and kept the screening task from becoming too unwieldy. The RWG believes that this approach and scope to screening accurately characterizes the

Columbia System Operation Review Recreation Influence Diagram

range of impacts that might be expected to occur by altering the system. Furthermore, the recreation models will be substantially refined in order to improve the precision of recreation impact estimates needed for full-scale analysis.

For the screening phase, spreadsheet models for three storage reservoirs — Dworshak, Libby, and Grand Coulee — were developed using new data sources and the best professional judgment of members of the RWG. A fourth model — Hungry Horse Reservoir — was constructed, but instead is based upon a quantitative model estimated from data collected during an onsite recreational user survey. These projects are very popular recreation areas and the U.S. Corps of Engineers and Bureau of Reclamation have access to good historical data bases on recreation usage, facilities, and lake elevations at these reservoir facilities.

The RWG did not include a free-flowing river stretch in its screening modeling efforts due to a lack of data on recreation activities occurring below Federal dams. Complicating the matter was that the hydroregulation alternatives analyzed in screening provided end-of-month pool elevations and flows, but not hourly or daily fluctuations in streamflow rates. The RWG felt that an end-of-month streamflow model would not sufficiently characterize impacts on water-dependent, free-flowing river recreation activities. Similarly, the RWG did not develop a run-of-river model for screening analysis since it was anticipated that most alternatives would not deviate outside of normal operating ranges at run-of-river projects. As it turned out, however, many of the screening alternatives (i.e., lower Snake River drawdown) caused run-of-river elevations and flow rates to fall outside of normal operating ranges. For those cases in which modeling capability was not developed for specific projects, the RWG addressed recreation impacts qualitatively rather than quantitatively. These qualitative assessments characterize the magnitude of recreation impacts expected to occur based upon the best professional judgment of RWG members.

The recreation models were structured using Excel software to simulate the effect of changes in system operations. Spreadsheet models for each sample project were constructed to estimate how variations in reservoir pool levels affect various forms of outdoor recreation opportunities. For the Grand Coulee, Dworshak, and Libby reservoir models, four of the most common types of recreational activities were included in the impact analysis: fishing, boating, camping/picnicking, and swimming; these models **do not** compute impacts for all forms of recreation available at these reservoirs, however. The rationale for selecting these activities was that the largest percentage of visitation falls into these four major categories according to historical data bases compiled by Federal and State agencies. Alternatively, the Hungry Horse model that was adapted did not distinguish among types of activities, rather it generates an aggregate estimate of impacts across all types of recreation activities.

Impacts on recreation activities are measured by estimating how recreation participation, expressed in visitor-hours, varies in response to a change in end-of-month lake elevations. The total annual impact on recreation usage is computed as the summation of the monthly changes in visitation for each recreational activity.

Assumptions

The methodological structure of the recreation models is based on lake elevation-recreation activity relationships, or "break points." Drawdowns in lake levels are known to produce undesirable effects on recreation, such as exposing mud flats, rendering boat ramps unusable, limiting shore access, and impairing overall lake aesthetics and visibility. Consequently, recreation activity, expressed in terms of visitation, is assumed to decline in direct response to reductions in reservoir elevations. The RWG established or adopted (i.e., Hungry Horse) such "break points" for each recreational activity at each project, where an estimate of the percent reduction in visitation was established as lake elevations

declined from full pool levels. In general, the "break points" are based on the best professional judgment and knowledge of RWG members and resource managers familiar with the specific project areas. The assumptions, justification, and rationale applied in developing these "break points" are provided for each sample project:

Dworshak. "Break point" information was based on information generated for the project during the 1988 low pool period, (U.S. Corps of Engineers (Corps), draft position paper on *Reservoir Refill-Advance Energy* (1988), and empirical data on recreation usage observed during periods of low pool. Additional information was furnished through professional observations and knowledge of outdoor recreation planners and project personnel located at the site. Table 3-2 summarizes the "break points" established for each recreational activity.

TABLE 3-2

DWORSHAK LAKE, IDAHO, RECREATION PILOT MODEL
"BREAK POINT" CRITERIA AND ASSUMPTIONS

Activity	"BREAK POINTS"; ESTIMATED IMPACT ON RECREATIONAL ACTIVITIES AT VARYING RESERVOIR OPERATIONAL RANGES				
	Optimum	Low Impact	Moderate Impact	High Impact	Severe Impact
General Comments	Full Pool 1600'; All facilities on the lake are 100% usable; optimum pool may be 1-2 ft. below full to expose small beaches.	Drawdown is noticeable; users may be inconvenienced or have some minor reduction in quality of recreation experience.	There is a significant reduction in water levels but facilities remain usable; effects on aesthetics quality of recreation experience are significant.	Many recreation facilities become unusable; there is a substantial decline in aesthetics and the quality of recreation experiences.	Inaccessible facilities, safety hazards, poor aesthetics, and other physical constraints nearly or entirely prevent participation in water-related recreation activities.
Boating (All Types)	1 to 2 ft. drawdown. Exposed small beaches provide optimum shoreline access. All boat facilities fully usable. Full visitor use.	>15 ft. drawdown. No significant effect on boating use. Full visitor use.	>25 ft. drawdown. All boat ramps remain usable. Access to docks difficult. Access to most minicamps eliminated. 30% reduction in visitation	>50 ft. drawdown. Only 3 of 7 boat ramps remain usable. Boat launching and access to marinas/docks difficult. Many exposed hazards. 75% reduction in visitation.	>155 ft. drawdown. Only 1 boat ramp usable (Big Eddy); requires long backup down steep slope. Many hazards exposed; stumps, shoals, islands. 100% loss in visitation.
Fishing (from boat or shore)	1 to 2 ft. drawdown. 90% of all fishing is from boats. Access for fishing is at optimum. Full visitor use.	>15 ft. drawdown. Exposed shoreline hazards and mudflats; not a serious constraint at this point. 10% loss in visitation.	>25 ft. drawdown. Boat access more difficult. Shoreline access requires crossing exposed mudflats. 30% reduction in visitation	>50 ft. drawdown. 3 of 7 boat ramps usable. Boat access difficult; bank fishing requires crossing exposed steep muddy banks. 75% reduction in visitation.	>155 ft. drawdown. only 1 boat ramp usable. 100% reduction in visitation.
Camping & Picnicking	1 to 2 ft. drawdown exposes many small beaches around shoreline providing optimum conditions for houseboat camping, swimming, etc. Aesthetic quality very high. Full visitor use.	>15 ft. drawdown. 10-20 minicamps unusable due to steep, muddy banks. Access from land-based facilities to shoreline hindered. Reduced aesthetic quality. 20% reduction in visitation.	>25 ft. drawdown. 40 minicamps unusable; most boat-in camping eliminated. Access from land-based facilities seriously constrained. 50% reduction in visitation	>50 ft. drawdown. Access to all minicamps is eliminated; no boat-in camping occurs. 75% reduction in visitation	>150 ft. drawdown. boating-related camping and access from shoreline facilities is virtually eliminated. 90% reduction in visitation.
Swimming	1 to 2 ft. drawdown exposes optimum beach areas. 75% of all swimming occurs at designated beaches. Full visitor use.	0 to 5 ft. drawdown. Two developed swim beaches and areas remain fully usable. Full visitor use.		>5 ft. drawdown. Only 2 developed swim beaches on lake; both usable but reduces at drawdown >5 ft. 75% reduction in visitation.	>10 ft. drawdown. Both developed swim beaches unusable. 100% reduction in visitation

Libby. "Break points" were based upon knowledge and information furnished by project personnel at the Corps Seattle District Office. Actual empirical data on the effect of low water levels on recreation usage were provided in a Corps document summarizing Lake Koocanusa project operations (August 1988). Additional "break point" information was collected from *A preliminary investigation of recreation, fisheries, and cultural resources and impacts on these resources if the reservoir is drafted deeper* (Corps Seattle District, October 1985). "Break points" used to develop the Libby model are summarized in Table 3-3.

TABLE 3-3

LIBBY DAM AND LAKE KOOCANUSA, MONTANA AND CANADA, RECREATION PILOT MODEL
"BREAK POINT" CRITERIA AND ASSUMPTIONS

Activity	"BREAK POINTS"; ESTIMATED IMPACT ON RECREATIONAL ACTIVITIES AT VARYING RESERVOIR OPERATIONAL RANGES				
	Optimum	Low Impact	Moderate Impact	High Impact	Severe Impact
General Comments	Full Pool 2459'; All facilities on the lake are 100% usable;	Drawdown is noticeable; users may be inconvenienced or have some minor reduction in quality of recreation experience.	There is a significant reduction in water levels but facilities remain usable; effects on aesthetics quality of recreation experience are significant.	Many recreation facilities become unusable; there is a substantial decline in aesthetics and the quality of recreation experiences.	Inaccessible facilities, safety hazards, poor aesthetics, and other physical constraints nearly or entirely prevent participation in water-related recreation activities.
Boating (All Types)	Full Pool All 10 boat ramps, 3 marinas and other facilities on the lake are fully usable. Full visitor use.	> 15 ft. drawdown Most boat facilities remain usable, but visitors are inconvenienced. 10% reduction in visitation.	>30 ft. drawdown. All 4 Canadian ramps and 1 US ramp unusable. Access down steep ramps becomes difficult. 30% reduction in visitation	>75 ft. drawdown. 6 of 10 boat ramps unusable. 30 ft. of drawdown = 300 ft. of boat ramp; boat access to water very difficult. 45% reduction in visitation.	>125 ft. drawdown. All boat ramps on the lake unusable. 100% loss in visitation.
Fishing (from boat or shore)	Full pool Fishing access is at its optimum. Most fishing is from boats. Full visitor use.	>15 ft. drawdown. Fishing access mostly tied to boating conditions. Shoreline fishing access crossing exposed shorelines. 5% reduction in visitation.	>45 ft. drawdown. Boat access more difficult. Shoreline access requires crossing exposed mudflats. 15% reduction in visitation	>75 ft. drawdown. 6 of 10 boat ramps usable. Bank fishing requires cross-steep banks and exposed mudflats. 45% reduction in visitation.	>155 ft. drawdown. All boat ramps unusable. 100% reduction in visitation.
Camping & Picnicking	Full pool. All day use areas, campgrounds and beaches are fully usable. Shoreline access at optimum. Aesthetic quality very high. Full visitor use.	>15 ft. drawdown. Access to lake from shoreline facilities is difficult. General aesthetic appearance declines. 10% reduction in visitation.	>22 ft. drawdown. 15% reduction in visitation	>30 ft. drawdown. Exposed banks leave land-based facilities long distance from shoreline. Poor overall aesthetic appearance. 25% reduction in visitation.	>155 ft. drawdown. boating-related camping and access from shoreline facilities is virtually eliminated. 100% reduction in visitation.
Swimming	Full pool. Designated swim beaches and areas fully usable. 90% of swimming occurs at 3 developed beaches. Full visitor use.	>2 ft. drawdown. Two developed swim beaches and areas remain usable but slightly reduced. 10% reduction in visitation.	>4 ft. drawdown. Swimming beaches usable but greatly reduced in area. 50% reduction in visitation	>5 ft. drawdown. All developed swimming beaches inoperable at drawdown >5 ft. 90% reduction in visitation.	>155 ft. drawdown. Developed swim beaches unusable. Access to shoreline very difficult. 100% reduction in visitation

Grand Coulee. "Break points" were established by the Bureau of Reclamation in consultation with the National Park Service. They were formulated according to what types of limitations are imposed on existing recreation facilities that accommodate public use (see Table 3-4).

TABLE 3-4

GRAND COULEE DAM AND LAKE ROOSEVELT, WASHINGTON, RECREATION PILOT MODEL
 "BREAK POINT" CRITERIA AND ASSUMPTIONS

Activity	"BREAK POINTS"; ESTIMATED IMPACT ON RECREATIONAL ACTIVITIES AT VARYING RESERVOIR OPERATIONAL RANGES				
	Optimum	Low Impact	Moderate Impact	High Impact	Severe Impact
General Comments	Full Pool 3560'. All facilities on the lake are 100% usable.	Drawdown is noticeable; users may be inconvenienced or have some minor reduction in quality of recreation experience.	There is a significant reduction in water level but facilities remain usable; effects on aesthetics quality of recreation experience are significant.	Many recreation facilities become unusable; there is a substantial decline in aesthetics and the quality of recreation experiences.	Inaccessible facilities, safety hazards, poor aesthetics, and other physical constraints nearly or entirely prevent participation in water-related recreation activities.
Boating (All Types)	1 to 2 ft. drawdown. all boat ramps, marinas, docks & other facilities fully usable. Exposed small beaches provide optimum shoreline access for boats. Full visitor use.	>5 ft. drawdown. All boating facilities remain usable. Drawdown becomes noticeable 5% reduction in visitation.	>10 ft. drawdown. All boating facilities remain usable. Access down steep ramps becomes difficult. Access to houseboat marinas is inconvenient. 15% reduction in visitation		>130 ft. drawdown. All boat ramps on the lake unusable. Some moorages at Keller Ferry still in the water but access to them is difficult. 100% loss in visitation.
Fishing (from boat or shore)	1 to 2 ft. drawdown. Most fishing is from boats. Fishing access from boats and shore is at optimum. Full visitor use.	>10 ft. drawdown. Fishing access mostly tied to boating conditions. Shoreline fishing access crossing exposed shorelines. 15% reduction in visitation.			>130 ft. drawdown. All boat ramps unusable. 100% reduction in visitation.
Camping & Picnicking	1 to 5 ft. drawdown. All day use areas, campgrounds and beaches are fully usable. Shoreline access at optimum. Aesthetic quality very high. Full visitor use.	>5 ft. drawdown. Access to lake from shoreline facilities is difficult. General aesthetic appearance declines. 5% reduction in visitation.	>10 ft. drawdown. Exposed banks and mudflats leave land-based facilities a substantial distance from water. General aesthetic appearance declines. 10% reduction in visitation		>130 ft. drawdown. boating-related camping and access from shoreline facilities is virtually eliminated. 100% reduction in visitation.
Swimming	1 to 3 ft. drawdown. Designated swim beaches and areas fully usable. 75% of swimming occurs at developed swim beaches. Full visitor use.	>3 to 5 ft. drawdown Most swimming beaches remain usable but unsafe conditions exist at some. 10% reduction in visitation.	>5 ft. drawdown. Swimming beaches usable but greatly reduced in area. 25% reduction in visitation		>130 ft. drawdown. Developed swim beaches unusable. Access to shoreline very difficult. 100% reduction in visitation

Hungry Horse. "Break points" were established using data taken from a 1989 recreation Contingent Valuation (CV) survey conducted for the Bureau of Reclamation, Pacific Northwest Region (Ben-Zvi and Associates, 1990, Contract No. 9 CS-10-10140). One of the primary objectives of the survey and subsequent modeling was to estimate a statistical relationship between reservoir levels and resultant recreation visitation patterns. The specific "break points" generated from the CV survey and used to develop the Hungry Horse screening model are given in Table 3-5.

TABLE 3-5

RECREATION PILOT MODEL
HUNGRY HORSE DAM AND LAKE, MONTANA
"BREAK POINT" CRITERIA AND ASSUMPTIONS

<u>Lake Elevation</u> ¹	<u>Visitation Loss Coefficient</u> ²	<u>Percent Use Remaining</u>
3560	0.00000	100
3555	0.00000	100
3550	0.02556	98
3545	0.12799	87
3540	0.22218	78
3535	0.30630	69
3530	0.38143	62
3525	0.44851	49
3520	0.50840	49
3515	0.56185	44
3510	0.60045	40
3505	0.60045	40

SOURCE: US Department of Interior, Bureau of Reclamation. 1990.
Evaluation of Non-Power Impacts From Reservoir
Drawdown. Ben-Zvi and Associates. Boise, Idaho.

¹ Measured in feet, National Geodetic Vertical Datum

² Percent of recreational visitation lost as the lake elevation declines.

METHODOLOGICAL PROCEDURES

The recreational pilot model assumes that the relationship between reservoir pool elevations and recreational visitation rates is positively correlated. Thus, a simple linear relationship was formulated as:

(1) $y = fn(x)$,

where,

y = percentage decrease in recreation use, and

x = lake elevation (ft) below full pool.

As described, the RWG established or adopted actual "break points" in pool elevations, where a physical effect on recreational activities could be anticipated. These "break points" relate changes in reservoir pool elevations to the expected percentage reduction in visitor usage. Applying the slope formula to calculate the slope of the line segment between "break points," the estimated percentage reduction in use for any given lake elevation can be computed as:

$$(2) y = m(x) + b,$$

where,

y = percent reduction in recreation use,

x = specified lake elevation,

m = slope of line segment $(y_2 - y_1)$

$(x_2 - x_1)$, and

b = intercept between line segments.

Using the estimated reduction in visitation interpolated from the slope of the appropriate line segment for a specified lake elevation (Figure 3-3), the estimated impact on visitation rates, weighted for seasonality of use, is computed as:

$$(3) \text{ v-hr} = (\text{h-use}) * (\text{m-use}) * (\text{y})$$

where,

v-hr = percent reduction in visitor-hours for a given type of recreation activity,

h-use = historical recreation usage (average annual visitor-hours from 1988-1990) for a given recreation activity and project site,

m-use = average monthly distribution of historical use (1988-1990) for a given recreation activity and project site, and

y = percent reduction in recreation usage estimated from equation (2).

The functionality of the initial model was improved by evaluating use reduction levels against the monthly recreation usage which would be estimated to occur given the historical average lake elevation levels. In this way, the model is able to estimate the monthly change in visitation resulting from any specified lake elevation as:

$$(4) \Delta y = y - y^*$$

where,

Δy = change in percent decrease in recreation usage

y = percent decrease in recreation usage from (2), and

y* = estimated percent decrease in usage at historical (1985-1989) monthly lake elevations.

By substituting y into equation (3), the corresponding change in recreation visitation (visitor-hours) is computed from the "original" graph in Figure 3-3. This provides the flexibility to evaluate the positive or negative effects of either drawdowns or refills in reservoir capacity on recreation participation. The range of uncertainty, represented by the "high" and "low" graphs, around the break points was established to conduct sensitivity analyses.

The SOR recreation screening models require that a designated end-of-month lake elevation be specified. The model computes the estimated monthly visitation rate, and corresponding percent reduction and monthly change in visitor-hours by type of recreation activity. By summing the monthly changes in visitation, the model computes the total annual impact on recreation at each project.

SENSITIVITY ANALYSES

Sensitivity analysis is applied to identify which primary input variables most significantly impact the value measure (i.e., total visitor-hours at each reservoir). Each parameter in the model was varied around a range of high and low values, and then inputted into the Supertree software program to test the resulting change in visitation. The larger the spread, or deviation in the value measure (visitor-hours), the more sensitive the input variable is in explaining a change in visitation. These variables were ranked according to their level of importance in "tornado" diagrams generated by the Supertree software. Those input variables that explained the largest variation in visitor-hours were then selected for the subsequent probability analyses of screening alternatives.

The following variables were tested through sensitivity analysis:

Decrease in fishing (bass and kokanee at Dworshak) given a change in reservoir elevation;

Decrease in boating given a change in reservoir elevation;

Decrease in camping and picnicking given a change in elevation;

Decrease in swimming given a change in elevation;

Shape of each activity usage curve; and

Hydrologic conditions for five representative water years

The results of the sensitivity analyses for Grand Coulee, Dworshak, and Libby Reservoirs are provided in Table 3-6. The data shows the input variables, ranked according to level of significance, chosen for the probability screening phase. Since the Hungry Horse Reservoir model does not distinguish among activities, sensitivity analysis was straightforward, involving only two input variables: aggregate recreation activity "break point" curve as a function of lake elevation, and hydrologic conditions.

TABLE 3-6
SOR RECREATION SENSITIVITY RESULTS

Grand Coulee

Fishing
Camp/picnic
Swimming
Hydrology
Boating

Dworshak

Kokanee fishing
Bass fishing
Boating
Camp/picnic
Hydrology

Libby

Fishing
Boating
Hydrology
Camp/picnic
Swimming

RESIDENT FISH WORK GROUP SCREENING PROCESS

PURPOSE

The focus of the Resident Fish Work Group's screening analysis was to: (1) model key uncertainties; (2) model key controlling factors; (3) analyze the effects of changes in reservoir operation on resident fish populations both in the reservoirs and in river reaches downstream; and (4) make recommendations to improve resident fish survival and production. While the full-scale analysis will attempt to look at how changes in river operations as a whole will affect all potentially impacted locations, screening considers only key reservoirs and stream reaches where reservoir operations were thought to have the largest and most direct impacts on resident fish populations. These locations are:

Dworshak Reservoir and the Clearwater River

Albeni Falls Dam/Lake Pend Oreille

Grand Coulee Reservoir

Libby Reservoir and the Kootenai River

Hungry Horse and the Flathead River

The Lower Snake River Reservoirs

John Day

Brownlee

DESCRIPTION OF SCREENING TECHNIQUE

A generic spreadsheet model to screen existing data was developed for the pilot analysis from the BPA document entitled: "Primary Screening Process for Assessing the Relative Effects of Proposed SOR Alternatives on Resident Fish" (Appendix A). This model was then modified and expanded to handle each of the reservoirs noted above for screening. The generic model was fashioned after a much more detailed model developed by the Montana Department of Fish, Wildlife, and Parks, specifically for Hungry Horse and Libby Reservoirs, referred to as HRMOD and LRMOD, respectively. Sample influence diagrams (Figures 3-4 and 3-5) depict the relevant relationships among the model variables for the generic reservoir and stream portions of the model, respectively.

FIGURE 3-4

Resident Fish Growth
RESERVOIR VALUE INDEX

FIGURE 3-5

Figure 2.

Resident Fish Growth
STREAM VALUE INDEX

The inputs to the spreadsheet models are average monthly reservoir elevations, spills, and streamflows. These inputs are obtained from the hydroregulation studies for each of the 90 alternatives and characterize the operation of the river system. Although the value measures in the generic model were based on a "generic" fish, the screening models were expanded to include site-specific impacts to species of concern (e.g., impact on kokanee's spawning success given changes in pool levels at Lake Pend Oreille) of the reservoir/stream reach system. Species/location-specific value measures were suggested by the appropriate regional experts with concurrence from the work group (see Appendix B for a list of the regional experts).

In order to highlight overall impacts at specific locations, a single combined value measure — referred to as a resident "fish index" — was defined by the experts as a linear combination of the individual site/species value measures. This site-specific weighted value measure was used throughout the subsequent sensitivity analyses and probabilistic assessments. (Note that linear weighting of an individual value measure does not reflect the value of maintaining species diversity, since the relative importance of a specific species does not increase even if pushed towards elimination at that location.)

The fish index is a relative measure of the health of the fish population in a specific reservoir or stream location. It ranges between 0 and 100 percent; 100 percent being the best for resident fish and 0 percent

being the worst. The health of the fish population in any location is dependent on the "health" of the location itself — which, in turn, is affected by the overall and site-specific operation of the river system. The "health" of a particular location, and therefore the health of the fish population, is defined in terms of basic habitat requirements that resident fish require to spawn, feed, and mature.

It is extremely important to note that the index scales are not comparable across locations; in other words, an 80 percent fish index at Hungry Horse under the base case alternative for example, is not necessarily "good" for fish at Hungry Horse, nor would a 50 percent fish index at Grand Coulee necessarily be "bad." At some reservoirs, such as Grand Coulee, the existing reservoir conditions are such that a 70 percent index may be the upper end of the achievable scale, and 100 percent may never be attainable. At other reservoirs, such as Hungry Horse, 100 percent is attainable and 80 percent represents the lower end of the scale of what has been experienced historically.

The following section describes the HRMOD and LRMOD process along with a general idea of modifications required for modeling at specific locations.

HUNGRY HORSE AND LIBBY RESERVOIRS

The Hungry Horse and Libby models represent the impacts to a generic fish in the reservoirs and downstream river reaches (i.e., Flathead and Kootenai Rivers). The original HRMOD and LRMOD were used with some modifications to correct deficiencies at reservoirs and downstream reaches. However, the pilot model has been expanded in the following ways.

The original model was retrofitted with reservoir specific data to increase sensitivity to site specific issues. Physical data for volume and surface area versus reservoir elevation were calibrated to each basin using digitized bathymetric data (resolution was based on topographical maps of the basin at 1 inch equals 400 feet).

Kootenai River output specific to white sturgeon was generated due to present concern for this species.

We replaced the generic indices describing the relationship between physical factors and biological trophic levels using analyses conducted from 1983 through 1991 at each reservoir. These revised relationships are:

X		Y
reservoir volume	vs.	zooplankton production
reservoir elevation	vs.	terrestrial insect deposition
area wetted bottom	vs.	benthic insect production
reservoir volume	vs.	phytoplankton production

All reservoir indices now incorporate simplified biological relationships from the full-scale Hungry Horse and Libby models.

For screening of alternatives, several intermediate calculations were added. Seasonal correction factors were added to increase the accuracy of the following intermediate values:

- total annual primary production
- total annual zooplankton production

- seasonal deposition of the four main order of terrestrial insects (Homoptera, coleoptera, Homoptera, Hemiptera)
- total annual benthic insect production.

The food items in their raw form (not corrected for season) are used to drive an index of food availability which is calculated monthly.

For the river component, we added:

- site-specific flow exceedance curves (post impoundment)
- flags to identify which alternatives had flows above 80th percentile exceedance flows (high flows are desirable because they re-sort gravel)
- high spring flows to initiate spawning
- site-specific wetted perimeter curves
- minimum flows are captured approximately by applying the Tennant method.

BROWNLEE RESERVOIR

Important species included in the fish index for Brownlee are: crappie, channel catfish, smallmouth bass, and rainbow trout. These species were chosen because of their importance to anglers.

To the generic model we added the effects of water level fluctuations on species' spawning. The generic model captured the effects of water management on "rearing" of these species. Species were then weighted based on their relative importance to anglers to determine the overall value measure at Brownlee.

DWORSHAK RESERVOIR AND THE LOWER CLEARWATER RIVER

The generic model was expanded to include kokanee, bull trout, westslope cutthroat trout, smallmouth bass, and the reidside shiner in the reservoir component, and rainbow trout in the river component. These species are believed to be significant for the following reasons:

- Kokanee is a major fishery, self-sustaining — the health of which is dependent on pool and flow management.
- Smallmouth bass is the most abundant self-sustaining littoral-based species in Dworshak and supports a fishery; this species is influenced by pool regulation.
- Redside shiner is an important native forage fish species, especially for bull trout and smallmouth bass. The reidside shiner is incorporated in the smallmouth bass portion of the model as food.
- The bull trout and westslope cutthroat trout are native species of special concern.
- Rainbow trout: this is an important recreational "put and take" fishery.

In developing the fish index value measure for Dworshak, we incorporated relationships that are known to affect the above named fish species:

- Smallmouth bass spawning/incubation success can be affected by downward fluctuation in pool elevations potentially causing dewatering of nests during the period lasting from May 15 to August 15. The reduction in pool elevation reduces the amount of smallmouth rearing habitat available overall. Upward fluctuation in pool elevation can reduce water temperatures at nest sites, causing nest abandonment or interruption of embryo development.
- Redside shiner is an important native forage species and is highly sensitive to pool fluctuations during its spawning period (May 1 to July 15). Thus, its spawning success is an important measure.
- The amount of acreage of suitable rearing habitat for rainbow trout is influenced by discharge at Dworshak Dam insofar as it influences total flow in the Lower Clearwater River.
- Low water levels may limit the number of streams which kokanee can access for spawning. However, the biggest factor limiting angling pressure is losses of kokanee through the dam. Both of these relationships are incorporated into the model representation of effect on kokanee.

LAKE PEND OREILLE - ALBENI FALLS DAM

The species included in this model (and inherently in its fish index) are: kokanee, rainbow trout, bull trout, and warmwater fish. Warmwater fish include largemouth and smallmouth bass, perch, and crappie.

Kokanee and rainbow trout were included as representative of the two main sportfish in the lake. Bull trout is an Idaho State sensitive species and Lake Pend Oreille supports the largest bull trout fishery in Idaho. Warmwater fish are important because they provide a significant low-tech, near-shore fishery which could be greatly expanded.

To the generic model we added relationships that are known to significantly affect sportfish. These relationships included:

- the effect of water level fluctuations on kokanee egg incubation,
- the effect of water level elevation on kokanee spawning (i.e., the location of spawning gravel),
- the effect of elevation on the ability of sportfish to access tributary streams,
- flows in the Clark Fork River and their effect on kokanee spawning,
- the effect of water elevation on the amount of overwintering warmwater fish habitat, and
- the effect of fluctuating water levels on the spawning and incubation of warmwater sportfish.

JOHN DAY RESERVOIR AND A GENERIC LOWER SNAKE RIVER RESERVOIR

The following species were included in these models: white sturgeon, smallmouth bass, largemouth bass, walleye, and northern squawfish. These species were selected because of their importance in affecting salmonid fishes — either as predators or competitors, their sport fishing value, and importance as resident species of concern in the Columbia Basin.

The following factors are of importance to each species and were incorporated in the models for these reservoirs:

- bass: spawning and incubation success affects the year class strength of bass,
- walleye: retention time in the Columbia River affects recruitment success (i.e., longer retention times enhance survival),
- white sturgeon: more riverine conditions favor white sturgeon, and
- northern squawfish: rearing habitat is the most limiting factor in the system which regulates the species abundance.

GRAND COULEE RESERVOIR

In addition to elevation and outflow, water retention time was added to the generic model for Grand Coulee. In past research on Grand Coulee, water retention time was found to contribute to fish entrainment and possibly nutrient and zooplankton losses through the reservoir. Because water retention time incorporates elevation and outflow, it is a good overall indicator of the biology of Lake Roosevelt and reservoir health.

Kokanee salmon was modeled because of its sensitivity to reservoir conditions and operations. It was determined that reservoir operations that were favorable for kokanee would be beneficial to other reservoir species. Therefore the value measures for Grand Coulee are kokanee growth and kokanee "left" (i.e., percent of the kokanee population left at the end of a year's time based on water retention times). These two components are then averaged to derive the fish index for Grand Coulee.

DESCRIPTION OF ASSESSMENTS

The list of assessments provides the possibility trees for the model variables. Ranges were constructed from regional fishery experts who shared their knowledge as part of their activity in the work group. A list of the assessments used in the generic model can be found in Appendix A.

For the stream portion of the models, the relationship of flow duration to discharge was needed to enable us to use the "S-1" and "S-2" charts in the "Primary Screening Process" document (See Appendices A and C). These summary charts were developed from the U.S. Army Corps of Engineers historical daily flow data recorded between 1975 and 1989. By plotting flow versus percent exceedance (i.e., the percent of the time a given flow was exceeded by higher flows), we can then read off percent exceedance for any given flow. We calculate discharge by subtracting percent exceedance from 100 percent. This percentage is then used to look up "wetted bottom" percentages on Chart S-1. For example, at Dworshak, an outflow (or discharge) of 10,000 cfs was exceeded about 14 percent of the time. Using 100 percent minus 14 percent = 86 percent as discharge on Chart S-1, one can see that at a flow exceeded about 14 percent of the time, "wetted bottom" is about 98 percent. The same process is applied in order to use Chart S-2.

SENSITIVITY AND PROBABILISTIC ANALYSES

A tornado diagram (Figure 3-6) illustrates the sensitivity of variables for the Grand Coulee model.

FIGURE 3-6

SENSITIVITY 4/30/92 18:09 Grand Coulee Fish

The widest, or top five, bars indicate the most sensitive variables which affect the fish index at Grand Coulee. This is important because these variables' ranges (i.e., high, medium, and low) were then used as inputs to the probabilistic analysis, in which we incorporated uncertainty. Other variables that may be important, but less sensitive, are held to their median value for the probabilistic analysis.

For example, of the variables impacting the Grand Coulee fish index the greatest are "Spring Water Retention Time," "Summer Food Production," "Zooplankton/Kokanee Growth," "Spring Food Production," and "Zooplankton Fall."

Probabilistic analysis was performed by varying the top two, three, or four most influential variables, as determined by the sensitivity analysis, for each modeled location. The probabilities for all variables were set at 0.25 for the low case, 0.50 for the medium case, and 0.25 for the high case, except for hydrology which was provided by the AMG.

The following conclusions can be drawn from the cumulative probability chart for the Grand Coulee model run under the base case alternative (Figure 3-7). The horizontal axis represents the range of possibilities of the Grand Coulee fish index. The vertical axis is the cumulative probability of achieving the associated fish index under the base case.

Certain conclusions can be drawn from the chart:

The 10th percentile fish index is about 18 percent which indicates that under this alternative, the fish index will be less than 18 percent, 10 percent of the time.

The 90th percentile fish index is about 52 percent which indicates that under this alternative, the fish index will be less than or equal to 52 percent, 90 percent of the time (or, conversely that it will be greater than 52 percent, 10 percent of the time).

There is zero probability that the fish index will be less than about 8 percent.

There is a 100 percent probability that the fish index will be less than any value above about 60 percent.

APPENDIX A

Draft: Primary Screening Process for Assessing the Relative Effects of Proposed SOR Alternatives on Resident Fish

Introduction

This process was intended for use in the preliminary screening of proposed operational alternatives in the System Operation Review.

The objective was to apply general relationships in river and reservoir dynamics discovered during the development of the reservoir-specific quantitative models, HRMOD and LRMOD. This resulted in the construction of a generic model, applicable to other storage reservoirs on the Colombia Basin. It was assumed that input to the model would be 14 values of reservoir surface elevation and river discharge. Input was to be monthly with the exception of April and August which were each divided into half-month periods (AP1 and AP2, AG1 and AG2). The intent was to calculate a value index for assessing the relative effects of proposed alternatives on reservoir and river "health" and ultimately resident fish.

This model employs an extremely simplistic, qualitative approach and has a limited application. It is not intended for the final analysis of operation alternatives. Major assumptions are listed within this text. It is entirely possible that something important will be inadvertently missed during the primary screening process. It was our understanding that errors resulting from the use of this model can be detected and corrected later in the SOR analysis.

Schematic of Process:

Explanation of the Reservoir Component:

- R-1a This curve represents a generic relationship between reservoir elevation and total storage (active plus inactive storage). A long narrow, steep-sided reservoir basin is assumed. Both axes are divided into 100 equal units. The portion of the y axis (elevation scale) which represents active storage must be calculated separately for each reservoir. For example: at full pool (3,560 ft. msl), Hungry Horse Reservoir contains 3,477,664 acre-feet of water. At the top of inactive storage (3,336 ft. msl), Hungry Horse contains 481,920 acre-feet of water, or 13.86 percent of total capacity. By entering the x axis at 13.86, and tracing a right angle at the curve to intersect the y axis, it can be seen that active storage begins at ≈ 42 and extends to 100 on the elevation scale. Given that $3,560 - 3,336 = 224$ feet and that $100 - 42 = 58$ units, we determine that $224 \text{ feet} \approx 58 \text{ units}$ or $1 \text{ unit} \approx 3.9 \text{ feet}$.

Similarly, Libby full pool (2,459 ft. msl) = 5,854,551 acre-feet and normal minimum pool (2,287 ft. msl) = 893,223.9 acre-feet, thus $1 \text{ unit} = 3.1 \text{ feet}$. Grand Coulee, Dworshak, and other Columbia River storage reservoirs can be calculated similarly. Reservoir elevation is linear from the end of month i (E_i) to the end of the following month j (E_j), so that all calculations per time step should be based on the mean elevation: $\text{Elevation} = (E_i + E_j)/2$. Mean monthly elevations can then be used to estimate the relative volume during each of the 14 time steps.

- R-1b The elevation scale calculated for R-1a can be used here to derive the relative surface area for each of the 14 time steps.
- R-2 Values of volume from R-1a can be entered here to estimate zooplankton production. Since the zooplankton life cycle is shorter than the monthly resolution of the model, season values may be calculated:

$Z_w = \text{winter zooplankton} = (\text{DEC} + \text{JAN} + \text{FEB})/3$.

$Z_{sp} = \text{spring zooplankton} = (\text{MAR} + (\text{AP1} + \text{AP2})/2 + \text{MAY})/3$.

$Z_s = \text{summer zooplankton} = (\text{JUN} + \text{JUL} + (\text{AG1} + \text{AG2})/2)/3$.

$Z_f = \text{fall zooplankton} = (\text{SEP} + \text{OCT} + \text{NOV})/3$.

- R-3 Values of surface area from R-1b can be assessed here to estimate benthic production. Benthic insects have variable life cycles from 4–5 weeks to several years. The extent of reservoir drawdown (dewatered substrate), therefore can effect production for more than one year. In general, benthic insects are more readily available to fish as food during spring and summer, but may contribute to the diet of insectivorous fish during the entire year.

The seasonal use of benthos by fish could be easily defined if we specified fish and insect species. Since we are trying to simplify the relationships however, the seasonal contributions of benthic insects may be best described as the annual average for one month:

$$B = \text{Seasonal Benthos} = (\text{DEC} + \text{JAN} + \text{FEB} + \text{MAR} + (\text{AP1} + \text{AP2})/2 + \text{MAY} + \text{JUN} + \text{JUL} + (\text{AG1} + \text{AG2})/2 + \text{SEP} + \text{OCT} + \text{NOV})/12$$

By averaging benthic production over the entire year, we attempt to capture the lasting effects on an extreme drawdown.

- R-4 Terrestrial insects are active in significant numbers during summer and fall. The abundance of insects deposited on the water surface from the land is dependent on surface area and distance from shoreline vegetation. Insects deposited on the surface may be completely eaten and replaced within one time step, so the calculation may be accomplished as follows.

$$T_s = \text{Summer Terrestrial} = (\text{JUN} + \text{JUL} + (\text{AG1} + \text{AG2})/2)/3$$

$$T_f = \text{Fall Terrestrial} = (\text{SEP} + \text{OCT} + \text{NOV})/3$$

Fish Growth

The gross assumption is that all species respond to temperature similarly. The following calculations of growth during winter, spring, summer, and fall are simply totaled to produce a Reservoir Value Index (RVI) which may range from 0 to 100:

$$F_w + F_{sp} + F_s + F_f = \text{RVI}$$

- F-1 Winter fish growth. Given the index described by:

$$I_w = \text{Winter Index} = (Z_w + B)/2.$$

We can enter the y axis to derive an estimate of relative fish growth (F_w) during the winter period. Averaging the various food types is intended to mimic opportunistic feeding behavior in a generic fish. The simple linear relationship in F-1 was designed to reflect temperature effects on fish growth. Otolith back calculations from salmonids collected in Libby and Hungry Horse Reservoirs showed that, on the average, only 2.3 percent of the total annual growth in length occurred during the winter (December through February).

- F-2 Spring growth. Given the index described by:

$$I_{sp} = \text{Spring Index} = (Z_{sp} + B)/2.$$

We can enter the y axis to derive an estimate of relative fish growth (F_{sp}) during spring. The y intercept at 5 units was intended to represent increased food requirements to compensate for a higher metabolic rate brought about by warming spring temperatures. Otolith back calculations showed that an average of 9.9% of total annual growth in length occurred during the period March through May.

F-3 Summer growth. Given the index described by:

$$I_s = \text{Summer Index} = (Z_s + B + T_s)/3.$$

We can estimate the relative growth (F_s) during the summer. The y intercept set at 20 units was intended to represent increased food requirements to compensate for a higher metabolic rate brought about by warm summer temperatures. Otolith back calculations revealed that, on the average, 57.3% of annual growth in length occurred during the period June through August.

F-4 Fall growth. Given the index described by:

$$I_f = \text{Fall Index} = (Z_f + B + T_f)/3.$$

We can enter the y axis to derive an estimate of relative growth (F_f) during fall. The y intercept set at 10 units was intended to represent decreased food requirements (as compared to the summer portion, F-3) brought about by declining fall water temperatures. Otolith back calculations showed that an average of 30.5% of annual growth in length occurred during the period September through November.

Assumptions:

1. Water temperature fluctuates naturally during the annual cycle.
2. Temperature effect on growth is constant during each season and influences growth in all species equally.
3. Wetted reservoir bottom is proportional to benthic insect production.
4. Zooplankton production responds proportionally to primary production as related to surface area and volume.
5. Benthic insects are available to fish as food at a constant rate throughout the year.
6. Terrestrial insects are only available to fish as food during summer and fall.

Explanation of the River Component:

- S-1 Discharge vs. Wetted Bottom. Discharge was divided into 100 equal units representing the flow duration curve in each river reach under examination. The discharge in each time step should be individually compared to the flow duration curve for the specific river to locate the correct position on the 100 unit scale. The relative value of wetted bottom

(W) can then be derived for each time step, then averaged within each season to produce W_w (winter), W_{sp} (spring), W_s (summer), and W_f (fall).

- S-2 Discharge vs. Habitat. As in S-1, the flow duration curve is compared to a generic Weighted Usable Area curve to estimate a relative habitat value (H). Time steps are then averaged within seasons to produce H_w , H_{sp} , H_s , and H_f . The shape of this curve may require modification at higher discharges.
- S-3 A food production index (P) should be calculated on a seasonal basis in the form:

$$P = (W + H)/2$$

to produce P_w , P_{sp} , P_s , and P_f .

Fish Growth

Season specific values of P are then used in relationships F-1 through F-4, respectively. As in the reservoir component, values of growth are simply summed to produce a value of Stream Value Index (SVI): $F_w + F_{sp} + F_s + F_f = SVI$.

Assumptions:

1. Water temperatures follow the natural seasonal regime and remain within the tolerance limits of fish and food organisms.
2. Temperature effect on growth is constant during each season and influences growth in all species equally.
3. Wetted river bottom is proportional to food production and available habitat.
4. No flow or temperature fluctuations occur within the 14 time steps (this model is inadequate to assess peaking operations or temperature perturbations).
5. Habitat reduction at discharges approaching flood stage are due to scouring within the river channel.

R-1a

Elev	Volume
0	0
10	1
20	3
30	6
40	12
50	19
60	30
70	42
80	57
90	76
100	100

R-1B

Elev	Volume
0	0
10	1
20	3
30	7
40	13
50	21
60	33
70	46
80	65
90	82
100	100

R-2**Zooplankton Production**

Volume	Low	Base	High
0	0	0	0
10	0.1	1	6
16	0.1	3	11
20	0.1	5	15
25	0.1	10	22.5
30	1	16	31
40	9	29	49
50	15	40	65
60	34	54	74
70	51	66	81
80	68	78	88
90	85	90	95
100	100	100	100

R-3

Benthic Production			
Surface Area	Low	Base	High
0	0	0	0
10	0.1	2	7
20	0.1	6	16
30	0.1	13	28
40	2	22	42
50	9	34	59
60	30	50	70
70	53	68	83
80	79	89	99
85	87.5	95	98.9
90	93	98	99.9
94	97	99	99.9
100	100	100	100

F-1

Food Prod. Index	Winter Growth
0	0
100	2.3

F-2

Food Prod. Index	Spring Growth
0	0
5	0
100	9.9

F-3

Food Prod. Index	Summer Growth
0	0
20	0
100	57.3

F-4

Food Prod. Index	Fall Growth
0	0
10	0
100	30.5

This table expanded on following pages.

River Discharge (total range)
vs. Wetted Bottom

River Discharge (total range)
vs. Habitat

Habitat Index
Food Production

R-4

Surface Area	Insect Disposition		
	Low	Base	High
0	0	0	0
10	0.1	1	4.5
20	0.1	3	10
30	0.1	6	16.5
40	0.1	11	25
50	0.5	18	35.5
60	15	29	43
70	30.5	41	51.5
80	50	57	64
90	72.5	76	79.5
100	100	100	100

S-1

Flow Duration	Wetted Bottom		
	Low	Base	High
0	0	0	0
10	0.1	0.5	2
15	0.1	1	3.25
18	0.1	2	4.7
19	1.15	4	6.85
19.5	5.075	8	10.925
19.75	21.0375	24	26.9625
20	39	42	45
20.5	66.925	70	73.075
23	72.55	76	79.45
25	75.25	79	82.75
27	76.95	81	85.05
30	79.5	84	88.5
35	83.75	89	94.25
40	87	93	99
45	88.25	95	99.9
50	88.5	96	99.9
60	91.3	97.3	99.9
65	91.25	98	99.9
70	93.75	98.25	99.9
80	95.75	98.75	99.9
85	96.75	99	99.9
90	97.75	99.25	99.9
100	100	200	100

S-2

Flow Duration	Aquatic Habitat		
	Low	Base	High
0	0	0	0
10	0.1	0.5	4
15	0.1	1	6.25
18	0.1	2	8.3
19	0.1	4	10.65
19.5	1.175	8	14.825
19.75	17.0875	24	30.9125
20	35	42	49
20.5	62.825	70	77.175
23	67.95	76	84.05
25	70.25	79	92.5
27	71.55	81	90.45
30	73.5	84	94.5
35	74.75	87	99.25
40	76	90	99.9
50	77.5	95	99.9
60	84	98	99.9
70	89.5	100	100
80	92.17	99.17	99.9
82	89.2	99	99.9
86	88.6	97	99.9
88	86.3	94	99.9
90	82.9	86.4	89.9
93	72.55	75	77.45
97	48.95	50	51.05
99	24.65	25	25.35
100	10	10	10

S-3

Linear	Habitat Index Food Production		
	Low	Base	High
0	0	0	0
10	5	10	15
20	10	20	30
30	15	30	45
40	20	40	60
50	25	50	75
60	40	60	80
70	55	70	85
80	70	80	90
90	85	90	95
100	100	100	100

F-1- Food Production Index

2.5% variability

Index	Low	Winter Growth	
		Base	High
0	0	0	0
10	0	0.23	.48
20	0	0.46	.96
30	0	0.69	1.44
40	0	0.92	1.92
50	0	1.15	2.40
60	0.38	1.38	2.38
70	0.86	1.61	2.36
80	1.34	1.84	2.34
90	1.82	2.07	2.32
100	2.30	2.30	2.30

F-2- Food Production Index

10% variability

Index	Low	Spring Growth	
		Base	High
0	0	0	0
5	0	0	5
10	0	.99	1.99
20	0	1.98	3.98
30	0.1	2.97	5.97
40	0.1	3.96	7.96
50	0.5	4.95	9.95
60	1.94	5.94	9.94
70	3.93	6.93	9.93
80	5.92	7.92	9.92
90	7.91	8.91	9.91
100	9.90	9.90	9.90

F-3- Food Production Index

15% variability

Index	Low	Summer Growth	
		Base	High
0	0	0	0
10	0	0	1.5
20	0	0	3
30	2.66	7.16	11.66
40	8.32	14.32	20.32
50	13.98	21.48	28.98
60	22.64	28.64	34.64
70	31.3	35.80	40.30
80	39.96	42.96	45.96
90	48.62	50.12	51.62
100	57.30	57.30	57.30

F-4- Food Production Index

5% variability

Index	Low	Fall Growth	
		Base	High
0	0	0	0
10	0.1	0	.5
20	2.39	3.39	4.39
30	5.28	6.78	8.28
40	8.17	10.17	12.17
50	11.06	13.56	16.06
60	14.94	16.94	18.94
70	18.83	20.33	21.83
80	22.72	23.72	24.72
90	26.61	27.11	27.61
100	30.5	30.5	30.5

Reservoir Elevation (Total Storage)
as Compared to Volume

Reservoir Elevation (Total Storage)
as Compared to Surface Area

Reservoir Volume
Vs. Relative Zooplankton Production

Surface Area
as Compared to Benthic Production

Surface Area
vs. Terrestrial Insect Deposition

Food Production Index
vs. Fish Growth (Winter Portion)

Food Production Index
vs. Fish Growth (Spring Portion)

Food Production Index
vs. Fish Growth (Summer Portion)

Food Production Index
vs. Fish Growth (Fall Portion)

APPENDIX B

Many resident fish experts around the region have contributed to the SOR process in order to provide the work group with the best knowledge available. Contributors are:

Idaho Department of Fish and Game:

- Melo Maiolie (Lake Pend Oreille, Brownlee)

Montana Department of Fish, Wildlife, and Parks:

- Brian Marotz (Libby, Hungry Horse)

Nez Perce Fisheries, Idaho:

- Dave Statler (Brownlee, Dworshak)

Upper Columbia United Tribes:

- Janelle Griffith (Grand Coulee)
- Al Scholz

Colville Confederated Tribes

- Kirk Truscott (Grand Coulee)

University of Idaho:

- Dave Bennett (Lower Granite, John Day)

APPENDIX C

River Discharge (Total Range) vs. Wetted Bottom

SECTION 3.4

WILDLIFE WORK GROUP SCREENING PROCESS

INTRODUCTION

The System Operation Review (SOR) Wildlife Work Group was formed to analyze and evaluate the effects of various Columbia River system operation strategies on the wildlife resource, specifically, those changes in river operations which could potentially affect the wildlife populations and their associated habitats. For purposes of the screening analysis, numerous operational alternatives were defined by the SOR work groups, other organizations, and the public at large. These alternatives were expressed as monthly changes in systemwide reservoir elevations and in-river flows. The Wildlife Work Group's subsequent evaluation of these alternatives was facilitated by the SOR decision analysis process. Decision analysis required the Wildlife Work Group to: clarify and identify key wildlife issues arising at projects within the geographic scope of the SOR; characterize the uncertainty surrounding selected value measures; and to develop an analytical model or tool capable of estimating the effects of changes in reservoir elevation or flows on wildlife populations and habitats. While full-scale analysis will measure systemwide changes, screening considered several key reservoirs and stream reaches where reservoir operations were thought to be representative of the most direct impact on wildlife values. Locations modeled include:

- Clearwater River measured at Spalding

- John Day Reservoir

- McNary Reservoir

- Little Goose Reservoir

Locations evaluated in a qualitative manner include the Federal storage projects:

- Dworshak

- Grand Coulee

- Hungry Horse

- Libby

- Albeni Falls

The following report documents the public issues, conceptual framework, assumptions, and methodological procedures used in developing the wildlife models; the key uncertainties surrounding them; and relevant factors involving the sensitivity and probability analysis.

PUBLIC ISSUES

The SOR public scoping phase identified few specific issues pertaining to the effects of regional hydropower system operations on the quality of the wildlife resource. However, general concerns for improving habitat conditions, and long-term wildlife productivity on a systemwide basis were expressed. A list of reservoir specific and systemwide issues was developed and will be further refined by the full Wildlife Work Group in various and ongoing open meetings around the region. The various value measures — indicator species and habitat — shown below were selected to represent conditions at free flowing river reaches, run-of-river projects, and areas adjacent to storage projects. Specific locations were chosen where existing data were available. A major assumption by the work group was to view screening as a quick and generalized process, useful for sorting and prioritizing regional wildlife trends for each of the 90 screening alternatives. This step was necessary to help identify a fewer number of alternatives which will be proposed for further study and described in the Draft EIS. At that time, the magnitude of near- and long-term effects of the full-scale alternatives will be analyzed by the work group.

CONCEPTUAL FRAMEWORK

In the initial phases of the screening process, the Wildlife Work Group developed a conceptual framework demonstrating the linkages between the input and outputs of the various reservoir models. The sample influence diagram (Figure 3-8) portrays the relationship between the physical parameters of the system, and the different effects to the wildlife resource or indicator to be measured. The reservoir models are spreadsheets driven by reservoir elevations or streamflows in five representative hydrologic water years which vary water quantity conditions from high to low. The monthly pool elevations or streamflow conditions and their duration and timing affect a wildlife population, habitat quality, or habitat area. These impacts are quantitatively measured as either changes in the number of individuals of a wildlife species, habitat acres, or habitat quality index.

WILDLIFE INFLUENCE DIAGRAM

The wildlife value measures are explained below for each of the selected locations.

1. Quantitative Measures

Canada Goose Nests. Goose nesting was used as a value measure at McNary, John Day, and the lower Clearwater River. This measure is based upon recorded nesting activity and the loss or gain of nesting sites, primarily islands, in the subject area.

Wetland/Riparian Acres. The acres are based upon vegetative cover mapping and the relationship between location and elevation of vegetation to water elevations under the different alternatives. This value measure was used at Little Goose and for the lower Clearwater.

Otter Den Sites-Habitat Suitability. This value measure is based upon three suitability indices used in a recent Habitat Evaluation Procedure (HEP) at Little Goose: density of shoreline vegetation, den site availability, and the distance from water to cover. The relationship of these three factors was used to determining the usefulness of an area for otter dens, reflecting riparian habitat and accessibility at various reservoir elevations.

Mallard Brood Habitat-Habitat Suitability. This value measure is based upon one suitability index — the relationship between the amount of wetland/riparian cover surrounding backwater acres. The data was collected as part of the HEP in the Little Goose area in 1989-1990.

Duck Broods. At John Day, estimates of broods produced at the Umatilla National Wildlife Refuge were used as the value measure. It reflects the change in shallow water habitats adjacent to emergent and/or wetland vegetation.

Wintering Mallards. In the John Day pool, wintering mallards show a strong relationship with the acres of field corn grown in the area. This value measure displays the degree of impact associated with reduced irrigated agricultural acreage in the John Day pool area.

Colonial Nesting Birds. This model reflects the amount of nesting activity on islands within the John Day pool. The availability of islands for colonial bird nesting period is required from April through July. These same islands are equally important for goose nesting earlier in the year.

Canada Goose Brooding. This model is based upon a HEP model used in a 1989-1990 study of the four lower Snake River reservoirs. It produces a habitat value for Canada goose broods based upon the nesting islands and pasture type habitats adjacent to the reservoir. This particular measure was used only for Little Goose in the screening effort.

2. Qualitative Measures

Reservoir Fluctuations. Reservoir drawdowns or fluctuations can be a major impact to wildlife values especially in the spring seasons as nesting and denning activities are initiated. Inundation of existing goose and other nesting sites or exposure to increased predation by the formation of land bridges to reservoir islands are common problems. Because insufficient empirical data on daily or weekly fluctuations was available for the screening process, a qualitative (spring timing) approach was used for screening purposes.

ASSUMPTIONS

The site-specific figures shown in Appendix A provide the possibilities for the model variables. Ranges were constructed by regional wildlife experts who shared their knowledge of conditions in the selected locations.

METHODOLOGICAL PROCEDURES.

1. Sensitivity and Probabilistic Analyses

The site-specific models were used to evaluate the 90 river operation scenarios. Sensitivity results are illustrated by the tornado diagram for the Hydrosim base case alternative at the John Day location (see Appendix B). For this particular model, the variables used are: Percent of Birds Eliminated by Fluctuation, Elevation vs. Canada Goose Nest Impacts, Hydrology (wet to dry), Elevation vs. Colonial Bird Impacts, Elevation vs. Duck Young Impacts, and Elevation vs. Mallard Brood Impacts. As shown, all variables have an impact on the value measures except for Mallards, which in this case are not affected because reservoir elevations do not drop below 262 feet.

Probabilistic analysis was performed by varying all of the variables in the above example. In other cases the top two, three, or four most significant variables, as determined by the sensitivity analysis were modeled. Due to a lack of available information, the Wildlife Work Group established probabilities for all of the variables which are shown in Appendix A. These are 0.25 for the low curve, 0.5 for the medium curve, and 0.25 for the high curve. Hydrologic probabilities established by the Analysis Management Group for the five water conditions were varied at 0.06, 0.18, 0.5, 0.18, and 0.08 (from the low to high water years).

2. Qualitative Assessment

A qualitative assessment was performed on the 90 alternatives in addition to the procedures outlined above. This procedure prioritized alternatives into four categories excellent, good, fair, and poor based upon timing of reservoir drawdowns and degree of impact to wildlife benefits. As shown in Table 3-7, the qualitative measure is based upon the timing of reservoir drawdowns. When combined with the results of the quantitative analysis wildlife benefits could be evaluated on a wider geographic area. The qualitative procedure was developed and used by the work group on a professional judgment basis.

TABLE 3-7

SOR WILDLIFE WORK GROUP ALTERNATIVE RATINGS

Table 1

EXCELLENT	<ul style="list-style-type: none">- No drawdown in storage reservoirs- Highest wildlife quantitative results
GOOD	<ul style="list-style-type: none">- Low drawdown in storage reservoirs (no spring drawdown)- Good wildlife quantitative results (above base case)
FAIR	<ul style="list-style-type: none">- Moderate drawdown in storage reservoirs (has spring/summer drawdown)- Moderate wildlife quantitative results (i.e. base case)
POOR	<ul style="list-style-type: none">- High storage reservoir drawdown and/or run-of-river drawdowns below M.O.P.- Poor wildlife quantitative results (below base case)

APPENDIX A

SITE SPECIFIC WILDLIFE MODELS

Mallards - Number vs. Elevation
John Day Pool, March thru Sept

Colonial Nesting Birds - Number vs. Elevation
John Day Pool, March through Aug

Duck Broods - Number of Young Produced vs. Elevation

John Day Pool, end of March - beg of July

Canada Goose Nesting - Elevation Impact

McNary Reservoir

Canada Goose Brood Rearing - Elevation Impact (HSIs)

Little Goose Reservoir

Mid Feb - June

Mallard Brood Rearing - Elevation Impact (HSIs)

Little Goose Reservoir

April - July

River Otter - Den Site Availability (SIs)

Little Goose Reservoir

River Otter - Shoreline Cover (SIs)

Little Goose Reservoir

River Otter - Distance to Cover (SIs)

Little Goose Reservoir

Wetland/Riparian Habitat - Elevation Impact (Acres)

Little Goose Reservoir

Clearwater Below Dworshak - Canada Goose Nests

Clearwater Below Dworshak - Wetland/Riparian

SENSITIVITY EXAMPLE

There are 4 value measures.

Display the results for value measure: 1

The low and high values for the sensitivity are: 217.78 305.64

Enter the low and high values for the plot: 200 325

Single or double spacing: DOUBLE -

Show variable description or name: DESCRIPTION

Show high/low modifiers: YES

Label for axis: Canada Goose Nests

There are 6 variables.

Enter the numbers of the first and last variables for the plot: 1 6

SENSITIVITY 10/16/91 12:37 Wildlife John Day Sensitivity

There are 4 value measures.

Display the results for value measure: 2

The low and high values for the sensitivity are: 600.00 600.00

Enter the low and high values for the plot: 590 610

Single or double spacing: DOUBLE -

How variable description or name: DESCRIPTION

Show high/low modifiers: YES

Label for axis: Total Number of Mallards

There are 6 variables.

Enter the numbers of the first and last variables for the plot: 1 6

SENSITIVITY 10/16/91 12:39 Wildlife John Day Sensitivity

There are 4 value measures.

Display the results for value measure: 3

The low and high values for the sensitivity are: 0.00 7480.00

Enter the low and high values for the plot: 0 7500

Single or double spacing: DOUBLE

Show variable description or name: DESCRIPTION

Show high/low modifiers: YES

Label for axis: Num. of Colonial Nesting Birds

There are 6 variables.

Enter the numbers of the first and last variables for the plot: 1 6

SENSITIVITY 10/16/91 12:40 Wildlife John Day Sensitivity

There are 4 value measures.

Display the results for value measure: 4

The low and high values for the sensitivity are: 1711.11 2211.11

Enter the low and high values for the plot: 1700 2300

Single or double spacing: DOUBLE -

Show variable description or name: DESCRIPTION

Show high/low modifiers: YES

Label for axis: Number of Duck Young Produced

There are 6 variables.

Enter the numbers of the first and last variables for the plot: 1 6

SENSITIVITY 10/16/91 12:48 Wildlife John Day Sensitivity

IRRIGATION WORK GROUP SCREENING PROCESS

Changes in the operational mode of the Columbia River system has the potential of affecting irrigation and municipality interests. As defined in the Scoping Document, the operational changes being considered in the Columbia River System Operation Review (SOR) is confined to the Columbia River Basin exclusive of the Snake River system above Brownlee Reservoir. The water rights for irrigation and municipal and industrial uses are to remain intact. However, the cost to divert the needed water supply, marketing costs of products produced and altered market outlets could change dramatically. Irrigation interests that divert directly from the lower Snake River and the Columbia River may find a significant investment is required to lower pump intake facilities as operational drawdown alternatives at major reservoirs are considered. The disruption of the navigation capability may also increase agricultural marketing costs and alter existing market outlets.

The impact of operational changes on navigation capability and its impact on the agriculture sector (irrigated agriculture and dryland farming agriculture) will be analyzed within the navigation functional area. The prospect of obtaining a water supply via new storage, conservation measures, leasing or other forms of water right acquisitions is currently beyond the scope of the SOR but needs to be evaluated and added to the base line condition being established through the SOR.

Prospects of acquiring the additional water through conservation, new storage, water right acquisition, etc., to meet the ever growing demands is currently being reviewed in other forums. These measures need to be thoroughly investigated to identify better potential levels of accomplishment and be in compliance with the National Environmental Policy Act process.

The initial screening activity of the agriculture and municipal and industrial functional area is confined to identifying incremental costs (capital investment and operation and maintenance) of extending and deepening pump facilities to accommodate reservoir pool drawdown proposals. The cost estimating model that is used in the initial screening of the 90 alternatives was developed from the summary analysis of costs to irrigation interests prepared for the Northwest Irrigation Utilities and the Umatilla Electric Cooperative. */

The analysis for the initial screening activity was confined to those reservoirs where major pumping activity exists and where the magnitude of incremental costs would be significant. This included pumping from Ice Harbor pool on the Snake River and from three reservoirs on the Columbia River: (1) Franklin D. Roosevelt Lake at Grand Coulee Dam; (2) McNary pool; and (3) John Day pool below the confluence of the Snake River with the Columbia River. Pumping from other reservoir pools will also be adversely affected but the order of magnitude is relatively small and did not impact the decision process during the initial screening phase. A full-scale analysis of a select number of alternatives resulting from screening will include impacts at all reservoir pools.

Figures 3-9 through 3-14 show the incremental costs that would be incurred as pool elevations decline. Estimates show a low range, midrange, and high range for both the capital and operating cost requirements at Ice Harbor, McNary, and John Day pools. The midrange is an indication of the most

*/ Northwest Irrigation Utilities, "The Impact of Lower Columbia and Snake River Reservoir Levels on Agriculture", 1991.
IRZ Consulting and PACAM Engineering Incorporated, "Effects of the Columbia River Pool Drawdown on Irrigated Agriculture in Oregon", July 1991, study sponsored by Umatilla Electric Cooperative Association.

probable impact. The high and low range values reflect the uncertainty in the estimates that have been made for screening analysis and is an attempt to quantify 80 percent of the total impacts (10 percent to 90 percent).

FIGURE 3-9

ICE HARBOR PUMPING COST MODEL

ADDED CAPITAL COST -[\$MILLIONS]

FIGURE 3-10

ICE HARBOR PUMPING COST MODEL

ADDED ANNUAL OMR&P COST -[\$MILLIONS]

FIGURE 3-11

McNARY PUMPING COST MODEL

ADDED CAPITAL COST -[\$MILLIONS]

FIGURE 3-12

McNARY PUMPING COST MODEL

ADDED ANNUAL OMR&P COST - [\$MILLIONS]

FIGURE 3-13

JOHN DAY PUMPING COST MODEL

ADDED CAPITAL COST -[\$MILLIONS]

FIGURE 3-14

JOHN DAY PUMPING COST MODEL

ADDED ANNUAL OMR&P COST -[\$MILLIONS]

Figure 3-15 shows the total cost of energy required to pump seasonal irrigation water to the Columbia Basin Project (based on 35 mills per kilowatt hour). This is the major pumping diversion from Franklin D. Roosevelt Lake (FDR) located behind Grand Coulee Dam. An estimate of pumping power requirements is based on the historic energy used to pump an acre-foot of water from FDR to Banks Lake with varying hydraulic head conditions.

FIGURE 3-15

FDR LAKE PUMPING COST MODEL

TOTAL ANNUAL POWER COST -[\$MILLIONS]

Tables 3-8, 3-9, and 3-10 show an estimate of the increased costs for different drawdown scenarios for Ice Harbor Dam, McNary Dam, and John Day Dam, respectively. Table 3-11 shows the total energy and estimated replacement cost of that energy to pump irrigation water during the irrigation season from FDR to Banks Lake.

TABLE 3-8

INCREMENTAL COSTS TO ENTITIES PUMPING FROM ICE HARBOR RESERVOIR POOL

SYSTEMS OPERATION REVIEW

Reservoir Characteristics	ICE HARBOR RESERVOIR POOL		
	Pool Elevation (feet msl)	Capital Cost Dollars	Annual OMR&P Cost Dollars
LOW RANGE ESTIMATE			
Normal Full Pool	440.0	\$0	\$0
Minimum Operating Pool	437.0	\$0	\$0
Normal Oper. - EL 440 to 437	436.0	\$0	\$0
Navigation Lock Sill @ EL 422	420.0	\$11,000,000	\$3,100,000
Spillway Crest	391.0	\$13,300,000	\$4,900,000
MID RANGE ESTIMATE			
Normal Full Pool	440.0	\$0	\$0
Minimum Operating Pool	437.0	\$0	\$0
Normal Oper. - EL 440 to 437	436.0	\$0	\$0
Navigation Lock Sill @ EL 422	420.0	\$16,500,000	\$4,300,000
Spillway Crest	391.0	\$20,100,000	\$5,900,000
HIGH RANGE ESTIMATE			
Normal Full Pool	440.0	\$0	\$0
Minimum Operating Pool	437.0	\$0	\$0
Normal Oper. - EL 440 to 437	436.0	\$0	\$0
Navigation Lock Sill @ EL 422	420.0	\$22,000,000	\$5,500,000
Spillway Crest	391.0	\$26,800,000	\$6,800,000

TABLE 3-9

INCREMENTAL COSTS TO ENTITIES PUMPING FROM McNARY RESERVOIR POOL

SYSTEMS OPERATION REVIEW

Reservoir Characteristics	McNARY RESERVOIR POOL		
	Pool Elevation (feet msl)	Capital Cost Dollars	Annual OMR&P Cost Dollars
LOW RANGE ESTIMATE			
Normal Full Pool	340.0	\$0	\$0
Normal Oper. - El 340 to 337	339.0	\$0	\$0
Minimum Operating Pool	335.0	\$7,300,000	\$2,900,000
	328.0	\$11,600,000	\$3,300,000
Navigational Lock Sill	320.0	\$14,000,000	\$3,800,000
MID RANGE ESTIMATE			
Normal Full Pool	340.0	\$0	\$0
Normal Oper. - El 340 to 337	339.0	\$0	\$0
Minimum Operating Pool	335.0	\$11,700,000	\$3,400,000
	328.0	\$15,800,000	\$3,700,000
Navigational Lock Sill	320.0	\$18,700,000	\$4,200,000
HIGH RANGE ESTIMATE			
Normal Full Pool	340.0	\$0	\$0
Normal Oper. - El 340 to 337	339.0	\$0	\$0
Minimum Operating Pool	335.0	\$16,000,000	\$3,800,000
	328.0	\$20,000,000	\$4,100,000
Navigational Lock Sill	320.0	\$23,300,000	\$4,500,000

TABLE 3-10

INCREMENTAL COSTS TO ENTITIES PUMPING FROM JOHN DAY RESERVOIR POOL

SYSTEMS OPERATION REVIEW

Reservoir Characteristics	JOHN DAY RESERVOIR POOL		
	Pool Elevation (feet msl)	Capital Cost Dollars	Annual OMR&P Cost Dollars
LOW RANGE ESTIMATE			
Normal Full Pool	268.0	\$0	\$0
Normal Oper. - EL 268 tp 265	263.5	\$0	\$0
	262.0	\$500,000	\$0
Minimum Operating Pool	257.0	\$8,400,000	\$2,200,000
Navigational Lock Sill	242.0	\$25,100,000	\$8,800,000
MID RANGE ESTIMATE			
Normal Full Pool	268.0	\$0	\$0
Normal Oper. - EL 268 tp 265	263.5	\$0	\$0
	262.0	\$5,000,000	\$0
Minimum Operating Pool	257.0	\$16,700,000	\$2,600,000
Navigational Lock Sill	242.0	\$50,100,000	\$10,000,000
HIGH RANGE ESTIMATE			
Normal Full Pool	268.0	\$0	\$0
Normal Oper. - EL 268 tp 265	263.5	\$0	\$0
	262.0	\$9,500,000	\$0
Minimum Operating Pool	257.0	\$25,100,000	\$3,000,000
Navigational Lock Sill	242.0	\$75,200,000	\$11,200,000

TABLE 3-11

TOTAL ENERGY COSTS TO PUMP IRRIGATION WATER FROM
FRANKLIN D. ROOSEVELT LAKE INTO BANKS LAKE
SYSTEMS OPERATION REVIEW

Pool Elevation (feet msl)	kWhr Per Acre-Foot Pumped	Quantity Water Used Acre-Feet	Total Annual Power Costs
---------------------------------	---------------------------------	-------------------------------------	--------------------------------

LOW RANGE ESTIMATE

1290.0	337.0	2,100,000	\$24,770,000
1273.0	350.0	2,100,000	\$25,730,000
1247.0	370.0	2,100,000	\$27,200,000
1224.0	390.0	2,100,000	\$28,670,000
1201.0	410.0	2,100,000	\$30,140,000

MID RANGE ESTIMATE

1290.0	337.0	2,600,000	\$30,670,000
1273.0	350.0	2,600,000	\$31,850,000
1247.0	370.0	2,600,000	\$33,670,000
1224.0	390.0	2,600,000	\$35,490,000
1201.0	410.0	2,600,000	\$37,310,000

HIGH RANGE ESTIMATE

1290.0	337.0	2,900,000	\$34,210,000
1273.0	350.0	2,900,000	\$35,530,000
1247.0	370.0	2,900,000	\$37,560,000
1224.0	380.0	2,900,000	\$39,590,000
1201.0	410.0	2,900,000	\$41,620,000

It is assumed that the increased costs required to continue the irrigation activity will not result in the economic collapse of the irrigated economy. Either the increased irrigation costs will be mitigated and the cost will not be borne directly by the agricultural interest or the cost will be within acceptable limits and irrigated agriculture will be able to absorb the increased costs and continue in an economically viable mode.

IMPACTS ON ALTERNATIVES

Economic impacts are based on incremental costs expected to occur as the base condition at each reservoir is altered. The characteristics of physical facilities as they exist today define the base case. Following is a description of the base case at each reservoir pool being evaluated.

- The minimum operating pool (MOP) at Ice Harbor Dam is at pool elevation 437 feet. Full pool condition is at elevation 440 feet. Normally, the operating range of the Ice Harbor pool for all water year conditions varies less than 1 foot from full pool (high and low water supply years). Capital cost at Ice Harbor pool would be incurred when drawdown falls below elevation 436 feet, which is 1 foot below MOP. Costs of operating the irrigation pumps increase as soon as the reservoir pool drops below full pool conditions. However, in this analysis increased operating costs were assumed to begin when the pool drops below elevation 436 feet.
- At McNary Dam and reservoir, MOP is at elevation 335 feet. In the base case, the normal operating range of the McNary pool for all water year conditions varies about 1 foot (between elevation 340 and 339 feet). Capital and annual operating costs would begin to accrue when drawdown falls below elevation 339 feet, 4 feet above MOP.
- At John Day Dam and Reservoir, MOP is at elevation 257 feet. In the base case, the normal operating range of the John Day pool for all water year conditions varies about 6 feet (between elevation 268 and 262 feet). The drawdown to elevation 262 feet (base case study) generally occurs during January through April. Pool elevation above 263.5 feet is maintained during the rest of the irrigation season. Diverters begin incurring capital investment costs and operation and maintenance cost at pool elevation 263.5 feet which is 6.5 feet above MOP. It was assumed that increased operational costs would begin to accrue at elevation 262 feet.
- Franklin D. Roosevelt Lake, behind Grand Coulee Dam, has a normal full pool at elevation 1,290 feet. The normal operating range is from elevation 1,290 to 1,208 feet. The pump system supplies water to the Columbia Basin Project to irrigate about 550,000 acres and benefits an additional 30,000 acres that is not included as project lands. Anticipated drawdown scenarios for this pool would not require any modification to the existing pump facilities. The economic cost identified in the screening process is the incremental change in power costs from the base case. The incremental costs incurred by a change in the system operation at Grand Coulee Dam would be based on a comparison of the base case to all alternatives being evaluated.

There are 21 alternatives that have slight to significant adverse impact on the irrigation community. These are in connection with the drawdown and major target flow alternatives and alternatives that include an extensive and intensive irrigation water conservation/new storage/water right acquisition program.

There are 52 alternatives that improve conditions slightly for the irrigation community. All other alternatives (17 in number) had little or no impact on the irrigation community. A summary of the irrigation/municipal and industrial impacts is given in Chapter 4.

SECTION 3.6

ANADROMOUS FISH WORK GROUP SCREENING PROCESS

INTRODUCTION

This section discusses the screening process and results as performed by the Anadromous Fish Work Group (AFWG) for the System Operation Review. The AFWG is responsible for analyzing the effects of changes in Columbia River system operations on anadromous fish populations. Anadromous fish spawn and rear in fresh water and then migrate to the ocean to mature before returning to fresh water to begin the cycle again. The primary species of concern in the Snake and Columbia Rivers are salmon and steelhead.

The screening analysis is the first step in evaluating the changes in anadromous fish response to different operational alternatives of the Federal hydroelectric system. The objective is to compare the alternatives and their effects on anadromous fish to aid in the development of operational strategies for full-scale analyses. The purpose is not to determine absolute magnitude of the impacts. Screening focused on Snake and Columbia River stocks in general, with no differentiation between wild and hatchery fish.

To screen operational strategies, AFWG selected value measures representing critical areas in which to compare fishery responses, selected models capable of quickly assessing the impacts in those areas, and collaborated on input values for the models together with the ranges of the uncertainty associated with the inputs. The discussion that follows is an overview of the AFWG screening process.

VALUE MEASURES

The AFWG selected three value measures necessary for a full-scale evaluation of the effects of system operations on the anadromous fishery resource. They are: (1) adult equivalents (adults below Bonneville Dam plus previous harvest); (2) downstream juvenile survival (including both timing and vitality); and (3) adult returns to the spawning grounds. These are shown on the influence diagram in Figure 3-16, along with the elements that affect fish survival.

FIGURE 3-16

INFLUENCE DIAGRAM FOR ANADROMOUS FISH

Realizing that calculating all of these value measures would be a formidable task, the group decided to narrow the list to include only downstream juvenile survival and travel time for the screening analysis. The full-scale analysis will contain information on all three of the value measures.

Indicator stocks were then selected. Originally, both spring and fall chinook were selected to span the range of the juvenile migration season. Stocks were chosen from each of the three distinct river reaches: the mid-Columbia, with fish originating above Wells Dam; the Snake River, with fish originating above Lower Granite Dam; and the lower Columbia River, with fish originating below McNary Dam.

Because data on fall chinook is extremely limited, trying to model fall chinook survival was difficult. There is no data relating flow to survival, and the little information available on fall chinook travel times and predation rates produced nonsensical survival results from the screening models, even given a broad range in the uncertainties. One of the two models used in screening was unable to evaluate fall chinook due to the lack of data necessary to parameterize the model. Therefore, for the screening analysis, the work group decided to report flow changes for these summer migrants. There is currently debate as

to whether increased flows aid fall chinook migration and survival. There is some data to support that increased flows decrease travel times, particularly for fish over 85 mm in length. The flows being reported are the averaged June and July flow at Priest Rapids and Lower Granite Dams, and the averaged mid-June through mid-August flow at The Dalles Dam.

SCREENING MODEL SELECTION

Three models have been developed within the region by various parties to evaluate downstream juvenile survival. They are the: (1) Passage Analysis Model (PAM), developed by the Northwest Power Planning Council; (2) the Columbia River Salmon Passage model (CRiSP.1), developed by the University of Washington Center for Quantitative Sciences; and (3) the FLUSH model being developed by the States of Idaho and Oregon and the Columbia Inter-Tribal Fish Commission. Rather than try and create a fourth model for SOR screening analysis, the work group decided to select from those already available.

Criteria for selection included that the model be computationally fast, accurate within an order of magnitude, able to evaluate the selected stocks, able to capture the uncertainty of input parameters, able to handle the five selected water years, and readily available. Two models were selected for screening: CRiSP.1 and PAM. The selection of two models enabled the AFWG to begin understanding and comparing models as well as highlighting additional uncertainty in the results. At the time of model selection, the FLUSH model was still being developed and not easily adaptable to our analysis. It may be used along with the other two models in the full-scale analysis.

CRiSP.1 and PAM both examine the passage and survival of juvenile salmon stocks through the Snake and Columbia Rivers and their tributaries to below Bonneville Dam. Overall fish survival is dependent on smolt survival through each reservoir as well as survival past each dam. Smolts collected in the bypass systems may be returned to the river or, at certain locations, be transported to a point downstream.

Both models are primarily accounting tools. A number of fish are introduced into the river system at a particular point and are tracked throughout their downstream migration. Fish are removed from the total at each dam and pool depending upon dam passage method and reservoir mortality. Neither model is able to address important biological factors such as interactions between stocks and fish condition. The output is percent fish survival from point of entry to below Bonneville Dam.

The primary difference between CRiSP.1 and PAM is that CRiSP.1 evaluates the mechanisms that contribute to reservoir mortality—such as dissolved gas levels, predator activity, and reservoir residence time—while PAM relies on a relationship between reservoir survival and flow based upon the Sims and Ossiander survival studies. The following sections give a brief description of each model.

CRiSP.1

The CRiSP.1 model is written in the C programming language and runs on a UNIX operating environment. It simulates juvenile fish survival through a series of dams and reservoirs.

Variability in input parameters is represented in the model by putting a range around the input variables and running a series of simulations in the Monte Carlo mode. Five hundred simulations were run for each operational alternative.

External inputs to the model include the flow, spills, and reservoir elevation (in the case of drawdown alternatives), from the hydroregulation models. CRiSP.1 reads the monthly average flow and spill for each period, January through November, and modulates these values into daily flows and spills to

simulate the daily variation in flows. The smolts experience these fluctuating flow and spill levels in the model as they migrate downstream.

Fish stocks may be input into the river system at a variety of locations. As mentioned earlier, the group chose to input fish into the head of Lower Granite and Wells pool, and below McNary Dam. Spring chinook releases (numbers and timing) were based on the 1985 passage indices at Lower Granite, Rock Island, and McNary Dams.

The model calculates the arrival of fish each day to each particular river segment before calculating passage to the next segment. The number of fish leaving a river segment on any given day depends upon the number arriving on that and previous days, dam passage survival, water flow rate, and mortality factors related to predation and gas bubble disease.

Dam passage survival depends upon the pathway that a fish takes past a dam. Fish arriving at the forebay can either pass over the spillway or go through the powerhouse. The fraction of fish entering the spillway depends upon the percentage of total flow being spilled and the timing of that spill. Fish entering the powerhouse can either pass through the turbines, or at those dams equipped with bypass facilities, may be guided into the bypass system. The portion of the fish being guided away from the turbines into the bypass system is represented by a fish guidance efficiency (FGE) value. Bypassed fish may be returned to the river below the dam, or at specified sites, may be transported downstream by trucks or barges. (In the screening analysis we focused on fish migrating in-river. We did not characterize the total population response by including those fish which would have been transported to below Bonneville Dam. Passage survival depends upon the route taken through the dam, with mortality accruing for spillway, bypass, and turbine passage.

The survival of smolts through the reservoir depends upon the predator density and activity, dissolved gas levels, and their migration rate through the reservoir. Predator activity in the reservoir is a function of water temperature and migration rate. Gas supersaturation levels depend on the amount of water spilled past the dam and the temperature. The smolt migration rates depend upon both fish behavior and the water velocity.

Calibration of the reservoir mortality function is done by varying the predation activity coefficient or adjusting the smolt travel time. The predation coefficient can be estimated based on the available predation data from John Day pool, or it may be estimated using the Sims, et al. 1983 reservoir survival data.

For the screening analysis we chose to estimate the predation activity coefficient by calibrating to the Sims et al. data. This makes the CRiSP.1 model more directly comparable with PAM, which uses this data for calculating the reservoir mortality. This fit yields higher mortality rates in low flow years than the John Day predation data implies. Even so, CRiSP.1 does not predict as high a mortality in low flow conditions as PAM does.

A complete description of the CRiSP.1 model can be found in Appendix A. It is entitled *Columbia River Salmon Passage (CRiSP) Model, Documentation for CRiSP.1* and is dated December 10, 1991.

PAM

PAM is a spreadsheet model originally developed using Quatro PRO software. It was initially developed to analyze Snake River stocks, and was called SNKPASS. It has been expanded to be able to include the mid-Columbia River. The AFWG is using an Excel version of PAM in order to interface with the Supertree software and evaluate uncertainty associated with input parameters. PAM analyzes downstream passage in much the same way as CRiSP.1, evaluating both dam passage and reservoir survival. However, PAM does not consider the components of reservoir mortality such as gas bubble

disease from supersaturated spill and predation activity. Instead PAM uses a derived flow/survival curve which is discussed below.

PAM relies on a period average flow generated from the hydroregulation models. For spring migrants in the mid-Columbia and Snake Rivers, we used the period average flow for the second half of April and May at Priest Rapids and Lower Granite dams, respectively. Flows for the lower Columbia were taken at The Dalles Dam and consisted of an average of May and 1.15 times the June flow. The migration period for spring fish through the lower river is approximately May through June 15. Because the hydroregulation models do not differentiate between the first and second halves of June, and because flows in the first half of June are generally 1.15 times higher than the monthly average, we chose the May/June weighted average for the period average flow value.

Amounts of planned spill for fish are specified within the model. Spill in excess of powerhouse capacity is calculated from the flow. Elevations are specified at the run-of-river projects for calculating the equivalent flow used to determine reservoir survival for drawdown alternatives and water particle travel time. PAM provides water particle travel time as output and does not attempt to relate it to fish travel time.

Dam passage parameters used in PAM are the same as those in CRiSP.1. Fish are passed over the spillway, through the bypass systems, or through the turbines. A survival estimate (range) is assigned to each of these passage routes. Again, no transport via barges or trucks associated with the bypass systems were modeled within PAM for the screening analysis.

Reservoir survival is a function of flow. PAM relies on a flow/survival curve derived from a regression analysis of period average flow and estimated system survival as measured by Sims and Osslander. Survival estimates were measured on the Snake River from the uppermost Snake River project to John Day or The Dalles for the years 1970, 1973, 1974, 1975, 1976, 1977, 1978, 1979, and 1980. PAM fits a polynomial, exponential and a broken stick function to the data points in deriving the flow/survival curves.

Because no data was available for the mid-Columbia and lower river, estimates were imposed upon these reaches by re-regressing the survival data with flows from the mid-Columbia and lower river. This created a set of flow/survival curves for these reaches.

For the drawdown alternatives PAM calculates an equivalent flow as if the projects were within normal operating elevations. It then relates that equivalent flow back to the flow/survival curves derived above. Therefore, PAM may be overlooking some important aspects of reservoir survival, such as gas bubble mortality due to increased spill, when evaluating the drawdown alternatives.

Additional documentation for PAM can be found in Appendix B, entitled *Passage Analysis Model - A Spreadsheet Model of Juvenile Fish Passage in the Columbia River*, dated April 24, 1992.

MODEL INPUTS, UNCERTAINTIES, AND SENSITIVITY

Most of the model input parameters have been discussed above. The Supertree software was used in conjunction with the PAM model to incorporate the uncertainty surrounding the key input variables. CRiSP.1 used a Monte Carlo process to incorporate the variable uncertainty. Table 3-12 shows the input variables and the range of uncertainty associated with each for the dam passage parameters for yearling chinook. Table 3-13 shows the FGE representing the portion of fish being guided away from the turbines into the bypass facility. The range associated with the dam passage parameters and FGE values were extracted from various published reports. These are the same for both PAM and CRiSP.1. Figure 3-17 shows the reservoir mortality curves PAM uses for the Lower Columbia River.

FIGURE 3-17

Reservoir Mortality/mile vs. Model Spring Chinook, Lower Columbia

—■— Polynomial —◆— Exponential —*— Broken Stick

TABLE 3-12

DAM PASSAGE PARAMETERS (YEARLING CHINOOK)

Item/Feature	Mean	Range
Spillway Mortality	2%	0 - 7%
Bypass/Sluiceway Mortality	2%	0 - 8%
Turbine Mortality	15%	10 - 24%

These passage parameters are applied at each dam. The appropriate value is applied to that proportion of the fish entering each passage route.

TABLE 3-13

FISH GUIDANCE EFFICIENCIES (YEARLING CHINOOK)

Project/Dam	Mean	Range
Lower Granite	63%	40 - 75%
Little Goose	73%	57 - 81%
Lower Monumental	73%	66 - 81%
Ice Harbor	78%	73 - 85%
Wells	80%	65 - 95%
Rocky Reach	0%	
Rock Island	0%	
Wanapum	0%	
Priest Rapids	0%	
McNary	75%	51 - 94%
John Day	72%	66 - 79%
The Dalles	43%	20 - 66%
Bonneville	42%	17 - 67%

The values shown above include those improvements that are expected to be operational by 1994.

Sensitivity analysis of these variables showed the hydrology, reservoir mortality assumptions, bypass, spill, and turbine survival assumptions to be most sensitive in evaluating in-river survival. Fish Guidance Efficiency and transportation survival become important when evaluating fish survival for the total population when transportation is implemented.

OUTPUT

All 90 alternatives were run using each model to determine the expected value, with the 10 and 90 percentiles bracketing the range of uncertainty. Model results are for spring chinook survival from above Lower Granite Dam on the Snake River to below Bonneville Dam, above Wells Dam on the Columbia River to below Bonneville Dam, and from below McNary Dam on the lower Columbia River to below Bonneville Dam. The AFWG chose to report both the overall (composite of all five water conditions) as well as the 1931 (low water condition) values. The 1931 water year was chosen for presentation because the low flow condition is the most limiting for adequate smolt migration in terms of both physical and hydrological conditions.

Also reported are the expected fish travel times for spring chinook from each river reach. In addition, summer flows are reported for each fish, as some parties contend they may affect fall chinook migration. Again, both overall and 1931 values are reported.

APPENDIX A

COLUMBIA RIVER SALMON PASSAGE (CRISP) MODEL DOCUMENTATION FOR CRISP.1

Columbia River Salmon Passage (CRiSP) Model

Documentation for CRiSP.1

Developed by the
Center for Quantitative Science
University of Washington
for the
Bonneville Power Administration
Division of Fish and Wildlife

DRAFT

*Monte Carlo and Scenario Forms of
Model*

December 10, 1991

Table of Contents

Abstract	3
Users Manual	4
CRiSP.1 Overview	4
History	4
General description.....	4
Species and stocks	5
Passage algorithms	5
Basics of Graphical Interface.....	6
Using the mouse	6
Control buttons	6
Slider inputs.....	7
Input histograms	7
Equation inputs.....	8
Model Application	9
RELEASE Information	11
RESERVOIR.....	11
BEHAVIOR DATA	12
FLOW.....	13
DAM.....	14
I/O.....	20
PASSAGE HISTOGRAMS	21
RUN THE MODEL.....	22
Monte Carlo	22
Analysis tool	23
Survival histogram	23
Installation and Start-up	24
Basic files	24
Parameter files.....	24
File Examples.....	25
all.base.dat	25
columbia.desc	25
summary.dat	26
.name.dat	27
Theory Manual.....	28
Model Computation Diagram	28
Reservoir Activities.....	28
Flow-elevation	29
Reservoir survival.....	31
Predation mortality.....	31
Supersaturation mortality	37
Nitrogen from spill	38
Nitrogen in tailrace	40
Nitrogen at Confluence	40
Nitrogen dissipation	40
Stochastic processes	41
Stochastic term probability density	42
Dam passage.....	43

Abstract

CRiSP is a computer model to simulate the effects of Pacific Northwest hydroelectric operations and fishery programs on passage and survival of juvenile salmonids in the Columbia River system. The model is under development at the University of Washington's Center for Quantitative Science under a contract from the Bonneville Power Administration's (BPA) Fish and Wildlife Division. The current model version generates scenarios of survival of fish releases through the river system.

Survival of hatchery and wild juvenile salmonid stocks are modeled in terms of:

- daily river flow,
- timing of fish entering the river system,
- reservoir survival,
- transportation and water spill schedules, and
- dam passage efficiency and survival information.

River flow is specified at headwaters.

CRiSP.1 tracks multiple fish releases and assigns passage and survival parameters to individual stocks. A model run covers migration of all stocks over a year. Input parameters describing fish behavior and system operations are specified for each year. Menu driven graphical input tools allow selection of specific combinations of parameters in a year.

Users Manual

CRiSP.1 Overview

History

CRiSP.1 is being developed at the University of Washington's Center for Quantitative Science. This document is for scenario generating and monte carlo forms of the model.

General description

CRiSP.1 models passage and survival of preselected salmon substocks through the Snake, and Columbia rivers and their tributaries to the Columbia River estuary (Fig. 1).

Fig. 1. Dams in system with fish migration and transportation routes

Fish survival through reservoirs depends upon:

- predator density and activity dependent upon water temperature,
- nitrogen supersaturation levels as dependent upon spill, and
- migration rate through a reservoir.

Fish migration rate depends upon:

- fish behavior, and
- water velocity which depends upon flow, cross-sectional area of a reach, and reservoir elevation.

Fish pass through dams via (Fig. 2):

- water spilled over the lip of the dam,
- turbines, and
- bypass screens in turbine entrances.

Fish collected in bypass systems can be returned to the tailrace or, at certain locations, transported to any point below the collection point in the river system.

Fig. 2. Dam showing fish passage routes

Species and stocks

The species and stocks of fish input to the river system are arbitrarily defined. Stocks are identified as yearling (spring) and subyearling (fall Snake and summer mid-Columbia) chinook salmon, steelhead, and sockeye salmon. The number of fish released at each site is identified on a daily basis. Each release group has a unique set of passage parameters.

Passage algorithms

The model calculates arrival of all fish on all days to each river segment before calculating passage of fish to the next downstream segment. With this complete set of arrival information it is possible to assign rules for fish transportation based upon a certain percent of the total run that will arrive at a dam. Thus, the model moves fish downriver a segment at a time, adding in daily those smolts coming from tributaries or hatcheries immediately upstream. The number of fish leaving a river segment on any given day depends upon the number arriving on the same and previous days, water flow rate (kcfs - 1,000 cubic feet per second), and mortality factors related to predation and gas bubble disease.

Dam operations control the main driving variables of the model; two major variables being daily total flows and spills.

Dam passage survival is dependent upon the pathway a fish takes past a dam (Fig. 2). Dams differ according to the possible passage pathway options. At all dams, fish arriving at the forebay can pass over the spillway, or through the powerhouse. The fraction of fish entering the spillway depends upon:

- percentage of total flow spilled, and
- timing of the spill period.

Fish entering the powerhouse can pass either through the turbines or be guided by traveling screens. The propensity of a population to be guided is represented by a fish guidance efficiency (fge) which is assumed constant over a season for each project and population. Mortality depends upon the pathway chosen with mortality accruing for spillway passage, collection, and turbine passage. Dam activities are calculated on a three hour basis and summed over a day to provide a daily fish input to the next reservoir.

Bypassed fish at specified dams may be transported in barges or trucks to any point in the river downstream of the collection site. Bypassed fish not transported are released into the tailrace. The model removes transported fish at a dam, computes a mortality, and releases fish at the transportation site at a later time as determined by the transportation velocity. Whether collected fish are transported depends upon rules developed to simulate actual transportation decisions. Transportation can be triggered by:

- flows,
- numbers of fish collected,
- a certain fraction of the total run of a specified species has passed a project,
- arrival of a given Julian day.

Basics of Graphical Interface

The CRiSP.1 model uses graphical interfaces to display and/or change data and equations in the model. The special tools developed for the model are described in this section.

Using the mouse

The graphical interfaces are operated with the mouse. The left mouse button, called the SELECT¹ button, opens a window. Move the mouse to a button on the menu and click once. A window appears (Fig. 3):

Fig. 3. Demonstrating mouse usage

The right button, the MENU button, is used to open a menu which stays open as symbolized by the "stick pin" in the upper left corner.

Control buttons

- Main panel has buttons to open menus.
- Click left (SELECT) to open first item in menu.
- Click right (MENU) once to open menu.
- Click left or right on pin to pin up menu.
- Repeat procedure to open submenus.

1. For more information see section on using the mouse in Sun System User's Guide of the Desktop SPARC set.

Slider inputs

Fig. 4. Slider input tool

Some menus have slider inputs to show and change parameters.

- To change the value put arrow on slider, hold down any mouse button and adjust value.
- The parameter in the model is immediately adjusted.
- Slider menus can be closed by putting arrow in window and hitting the "Open" key on keyboard. They may also be closed by clicking left on the pin in the upper left corner.

Input histograms

Fig. 5. Input histogram

Input histograms allow rapid input and visualization of data that vary during a day.

- Continuous input: hold left button down and draw curve.
- Step function input: click left button once, move mouse, click middle button once.
- Increase graph scale: click right button in upper half of graph.
- Decrease graph scale: click right button in lower half of graph.
- Read arrow coordinate: two numbers on lower coordinate change with X Y position of mouse arrow.

Equation inputs

Fig. 6. Equation window

Equation windows allow for selection of equations from a list; setting equation parameters and visualizing characteristics of the equation in a graphical window. The window includes the following functions:

- **① Location** - identifies where to apply equation.
- **② Species** - identifies which species the equation applies to.
- **③ open spill schedule windows** - allows equation data to be input on a daily basis.
- **④ activate/save displayed equation** - after making changes in a window this button activates changes in the model. Note they are *not* automatically saved on disk through this procedure.
- **⑤ reset equation** - to return to previous setting of equation parameters.
- **⑥ Equation** - a menu of equations.
- **⑦** Equation parameters set by slider bars, up to five parameters can be identified.
- **⑧** Graphic showing equation characteristics, dynamically changes as parameters change.

Model Application

CRiSP.1 in its current form is used in two basic ways:

1. A *scenario* generating form to study the effects of changes in various system parameters on the survival and migration of fish during a season. The model provides the user with a way to gain an understanding of the interaction of factors which determine fish migration and survival.

Five basic groups of data can be changed in the model:

- release information,
 - reservoir information,
 - behavior information,
 - flow information, and
 - dam operation and spill information.
2. A *Monte Carlo* form is used to run a series of different water years to determine the probability of survival of over a number of water years and/or Monte Carlo games. The results of the Monte Carlo games are stored in a file system and the survival probabilities can be view through an Analysis tool.

These data groups are accessed through a control panel (Fig. 7). In addition, the panel contains buttons to show passage information as well as to enter data into the model.

Fig. 7. CRiSP.1 control panel

The different modes are obtained through the RUN THE MODEL button and are illustrated below:

Fig. 8. Modes of analysis accessible through the run the model button.

- scenario makes one model run
- monte carlo runs several runs using a flow file generated from a hydro-model and a base file supplying other parameters
- analysis provides a tool to analyze monte carlo runs
- display map brings up the map of the river

The river map of the river that is defined by the *columbia.desc* file (Fig. 9). The map contains dam sites, fish release sites, and river segments. The map is interactive with the model.

- Moving the mouse arrow over the map identifies objects.
- Clicking left on a river segment or dam opens a passage histogram of survival information at that spot.
- Clicking right on a release site opens a fish release window.

Fig. 9. River map showing river segments, dams and release sites

RELEASE Information

Information on numbers of fish released and where they are released is assessable through the RELEASE button on the control panel or clicking right on a fish image on the map. When using the RELEASE button, submenus appear from which to *add* a new release or *modify* an existing release.

Fig. 10. Release window

These procedures activate a release window that contains:

- **Release data** - defines the state of the release.
 - NEW: a site not active in the model
 - EXISTING: an active site
 - EXISTING, NOT ACTIVE: appears when changes are made to an existing site
- **Releases Start (Julian days)** - determines the first day of a release.
- **Age at Release Start (days)** - determines the age of fish at first release. This capability is included so fish passage behavior can be related to fish age as well as time in the river.
- **Release Site** - identified release site.
- **Species** - identifies species of release.
- **set release counts** - an input histogram to define number of fish released each day since start of release. Time is relative to start time.
- **create new release** button to activate a NEW release.
- **delete this release** button to delete a EXISTING release.
- **activate changes** button to change an EXISTING release.
- **restore previous values** button to restore values to previous setting.

RESERVOIR

This button changes parameters specific to a given reservoir and mortality for fish while they are traveling through the reservoir and segments of the river. The RESERVOIR button has a submenu with three inputs (Fig. 11).

Fig. 11. RESERVOIR button and the submenu that opens

Equations using data are described in the section on model theory (section on page 3).

- predator density - to change predator density in the river segments. Numbers are in predators per square kilometer of river surface area.
- water temperature - river temperature on a daily basis (Julian days) is input here. River temperatures for each headwater are defined.
- river parameters - allows changes in two model parameters:
 predator_act_exp (1/C) defines predator activity change with temperature,
 gas_dissp_exp (1/day) defines nitrogen supersaturation dissipation over time.

BEHAVIOR DATA

Survival and migration rates depend upon species specific parameters that are classified as behavioral data. The rates depend upon species specific fish behavior (Fig. 12).

Fig. 12. Behavior data button and submenu

- Vb - an input histogram that defines fish swimming velocity along river axis. This can change as a function of fish age. Positive values indicate downstream swimming in miles per day. Negative values indicate upstream swimming.
- Vvar - an input histogram that defines the variance in the net velocity of fish migration along the axis of the river.
- drift time - an input histogram that defines the percent of the day that fish are subject to movement with the water velocity.
- pred coef - sets mean and coefficient of variation of the predator mortality coefficient for each species.

- gas mort thresh- a gas mortality threshold is set by slider. This defines a level of supersaturation below which not gas bubble disease occurs.
- gas mort coef - sets mean and coefficient of variation of nitrogen supersaturation mortality coefficient for each species.
- gas mort exp - sets mean of the nitrogen supersaturation mortality exponent for each species.

FLOW

The FLOW button allows input of flows to the river system at dams and headwaters, to remove water for irrigation, and change the reservoir and river segment elevation levels (Fig. 13). Flows in all river segments are determined from the flows generated in headwaters and flow inputs and losses in each river segment from irrigation. Flows can also be input by specifying flows at every dam. Differences in flows between two adjacent dams goes into the reservoir between them:

- dams - daily flow at dam in kcfs.
- headwaters -
flows: daily flows at headwaters (kcfs)
unreg max: maximum flow possible in unregulated headwaters (kcfs). The default values are determined by cross-sectional areas of the streams.
- loss - daily loss of river water due to irrigation withdrawal from the reach.
- elevation - daily elevation of river segment below full pool. Changing elevation changes river velocity for a given flow level.
- propagate up - balances the flow loss in reservoirs to account for differences in the flows at dams. Differences in flows at dams are attributed to loss in river segments.

Fig. 13. Flow button showing submenus for different flow elements

DAM

Parameters that can be altered at each dam include transport rules, spill, nitrogen supersaturation generated from spill, predation at the face of the dam, diel passage distribution, mortality in different routes through a dam and fish guidance efficiency.

The submenus are illustrated in Fig. 14 and defined below.

Fig. 14. Button to change dam parameters

- Transport

The transport window is illustrate in Fig. 15.

The image shows a 'Transportation Parameters' window. At the top, it says 'Transport Record Type : EXISTING, NOT ACTIVE'. Below this are two dropdown menus: 'Transport Dam: McHary Dam' and 'Existing Transports'. Under 'Release Reach:' is a dropdown menu showing 'Estuary'. The 'start transportation:' section has two radio buttons: 'by day' (selected) and 'by count'. Below this is a slider for 'start on day' with values 57, 0, and 220. The 'stop transportation.' section has a slider for 'on day' with values 200, 0, and 220. Below that is a slider for 'or if daily count below' with values 500, 0, and 2000. Then a slider for 'for required # days' with values 5, 1, and 10. The 'start and stop separation:' section has a dropdown for 'species to separate:' showing 'Chickadee', and a 'Set Separation Probabilities' button. Below this are two sliders: 'start if flow > (kcfs)' with values 125, 0, and 200; and 'stop if passage > (%)' with values 80, 0, and 100. At the bottom is a slider for 'transport speed (mi/day)' with values 100, 0, and 500. At the very bottom are three buttons: 'Activate this transport record', 'delete this transport record', and 'reset values'.

Fig. 15. Transport window

Rules to start and stop transport are:

- **Transport Record Type** - defines the state of the release.
 - NEW: a transport record not active in the model
 - EXISTING: an active transport record
 - EXISTING, NOT ACTIVE: appears when changes are made to existing record
- **Transport Dam** - menu of dams from which transported fish can be collected.
- **Release Reach** - reach of river into which transported fish can be released.
- **start transportation** - method by which transportation is started
 - by day: Julian day to start transportation,
 - by count: number of fish that must pass a dam on a given day to start transportation at the dam.
- **stop transportation** - transportation can be stopped by specifying
 - day: Julian day to stop transportation,
 - count: a target fish count for a certain number of days that the actual count is below,
 - required # of days: number of days required for daily count to be below that specified on line above.
- **start and stop separation** - separators in bypass systems of dams have the ability to separate and return small fish to the tailrace. Separators are used when the flow is above a given amount. At McNary Dam this amount is 220 kcfs and at Little Goose Dam, 100 kcfs. Separation is stopped if 80 percent of the yearling chinook have passed¹. Specific settings of the separation algorithms are
 - species to separate: default subyearling chinook
 - set separation probability: default is subyearling chinook = 80% other species separation = 20%
 - start if flow > (kcfs): 220 for McNary, 100 for Little Goose
 - stop if passage > (%): 80%.
- **Transport speed (mi/day)** - barge or truck transportation speed to release site.
- button to activate a NEW record or CHANGE an EXISTING record
- button to delete an EXISTING record
- button to reset values in an EXISTING record.

- Spill

A spill submenu allocates parameters related to spill schedules and fish passage effectiveness on a dam and species specific basis (Fig. 16).

1. From the Fish Passage Plan for 1991 Corps of Engineers publication CENPD-PE-WM March 1991

Fig. 16. Spill effectiveness window

The following parameters can be set in the window:

- **Dam** - dam to which record applies.
- **Species** - species to which record applies.
- **open spill schedule windows**- -input histogram windows defining percent of river spilled each day and each night over the season.
- **activate/save displayed equation** - after making changes in a window this button puts changes in model. (Note: they are *not* automatically saved on disk.)
- **reset equation** - to return to previous setting of equation parameters
- **Equation** - a menu of equations to describe spill efficiency of the form $Y = f(X)$
- **a** - equation parameter set by slider bar
- **b** - equation parameter set by slider bar
- **var** - variance term in equation set by slider bar (e in equation menu)

- Nsat

A submenu defining nitrogen supersaturation as a function of spill on a dam specific basis is illustrated in Fig. 17.

Fig. 17. Nitrogen supersaturation equation window

The following parameters can be set in the window:

- **Dam** - dam to which record applies.
- **activate/save displayed equation** - after making changes in a window this button puts changes in model. (Note: they are *not* automatically saved on disk.)
- **reset equation** - return to previous setting of equation parameters.
- **Equation** $Y = b \cdot X + a \cdot (1 - \exp(-kX))$
 Y = nitrogen supersaturation in percent above 100% saturation.
 X = river spilled in kcfs
 a , b and k are model coefficients exponent set by slider bar.

- Predation & Passage

A submenu defines predation at the dam and probability of passage on a three hour time interval on a dam and species specific basis (Fig. 18). The predation probability represents the probability the predation will occur within a specified interval of the day. This feature can be used to represent the decrease in activity of visual predators at night. The passage probability represents the probability of entering the dam within two hour segments. Passage is expressed as a binomial distribution and, depending upon the probabilities, fish experience no delay in passage or they can be delayed for days.

- Predator Density

Predator density in the forebay and tail race at each dam are specified through sliders.

- Tailrace residence time

The model describes the residence time of fish in the forebay for use in calculating predation in the tailrace. This value is set by a slider. An option to relate residence time to flow in the project will also be included.

Fig. 18. Predation and passage probabilities at dam

- Forebay Delay by flow

The model allows a delay of fish in the forebay depending on the flow through the dam relative to the hydraulic capacity of the dam. This feature has a sigmoid distribution for so delay only occurs when the flow is significantly smaller than the hydraulic capacity. The reasoning behind this feature is that with lower flows the number of turbines in operation is less and there is no forced spill so fish should take more time passing a dam. The equation is set by an equation window (Fig. 19).

Fig. 19. Delay in dam passage as a function of flow in percent flow hydraulic capacity.

- Mortality

A submenu defines fish mortality in various passage routes (Fig. 20). Mean and variance of mortalities are specified for each route, for each dam, and for each species. The probability distribution of each passage route is defined by a truncated normal distribution that is confined within the range 0 to 1.

mean		variance	
Sonneville Dam			
Spillway	0.00	0.00	0.00
Bypass	0.00	0.00	0.00
Turbine	0.00	0.00	0.00
Transport	0.00	0.00	0.00
The Dalles Dam			
Spillway	0.00	0.00	0.00
Bypass	0.00	0.00	0.00
Turbine	0.00	0.00	0.00
Transport	0.00	0.00	0.00

Fig. 20. Input window for dam passage mortality

- FGE

A submenu defines fge for day and night periods (Fig. 21). Mean and variance of fish guidance are specified for each route, for each dam, and for each species. The probability distribution of each passage route is defined by a truncated normal distribution that is confined within the range 0 to 1.

mean		variance	
Sonneville Dam			
day	0.00	0.00	0.00
night	0.00	0.00	0.00
turbine	0.00	0.00	0.00
transport	0.00	0.00	0.00
The Dalles Dam			
day	0.00	0.00	0.00
night	0.00	0.00	0.00
turbine	0.00	0.00	0.00
transport	0.00	0.00	0.00

Fig. 21. Fge window

- Dam survival

A submenu opens a window to illustrate the probability distribution of dam survival generated with the given setting of dam parameters (Fig. 22). Running the submodel calculates survivals for 20 Monte Carlo runs using the selected parameters.

Fig. 22. Example of dam survival probabilities

I/O

Parameters can be input and stored as a complete file or in groups corresponding to the information assessable through the main panel buttons. The I/O window and its submenus is illustrated in Fig. 23.

Fig. 23. I/O window and submenus

Window ❶ allows input and output of all model parameters and lists the data in the directory. Functions and data stored are:

- List - list data in the directory in which CRISP.1 was started.
- Read - reads in a specified data file indicated on Data File line ❷. Depending upon submenu item Read ❸ either replaces data in the model or appends additional data. Append applies when reading in additional release site information.
- Write - menu ❹ allows writing data into a file ❷ designated by the categories
 - All: complete data in the model at the moment.
 - Species: all information for each species
 - predator coefficient mean and coefficient of variation,
 - gas mortality coefficient mean and coefficient of variation,

gas mortality exponent,
swimming speed,
migration speed variance,
migration drift time.

Spill: percent spill in day and night periods for each day at each dam.

Reservoir: information specific only to predators in reservoirs
predator density.

Flow: all flow information at headwaters and reservoirs including
flow (kcfs) on a daily basis,
reservoir loss (kcfs) on a daily basis,
elevation (ft) on a daily basis,
flow maximum (kcfs),
flow coefficient relating flow to velocity.

Dam: all guidance and mortality factors for each dam and species including
spill mortality mean and variance,
bypass mortality mean and variance,
turbine mortality mean and variance,
transportation mortality mean and variance,
separation probability,
predation in forebay,
probability passage into a dam,
fish guidance efficiency mean and variance for day and night.

River: information on physical properties of river water including
water temperature,
gas dissipation exponent,
predator activity exponent.

- Clear - menu **C** clears all release and transport data from the active memory of the model. This menu does not effect disk files.

PASSAGE HISTOGRAMS

Fig. 24 shows the button for passage histograms which illustrates the number of fish passing a river segment or dam each day, the cumulative number that eventually pass over the season and the percent survival on a species basis. In addition any passage histogram can be opened by putting the mouse pointer on the segment or dam desired and clicking left.

Fig. 24. Passage histogram for Bonneville Pool

RUN THE MODEL

After the model configuration is set as desired click the RUN THE MODEL button. The progress of calculations will be displayed at the top of the map. After running the model it will write survival results to the lowest point in the river in the summary.dat file. This may be studied by double clicking the icon in the file manager.

Fig. 25. To run the model in warp drive double click the Enterprise

Monte Carlo

The Monte Carlo mode is accessed through RUN THE MODEL button.

Fig. 26. Monte Carlo Window.

The window allows input of the following:

- add / delete alternative List ① allows a selection of alternatives to be defined in the model run. An alternative is a list of data files and a flow archive file.
- Flow Archive ② is the file name consisting of period averaged flows at dams as computed by a hydro model such as HYSSR, HYDROSIM or SAM.
- run monte carlo ③ runs the number of simulations games and simulation years
- Model progress ④ indicates the progress in running the list of options.

Analysis tool

The results of a monte carlo run can be viewed with the analysis tool depicted below.

Fig. 27. Analysis tool menu.

The analysis tool provides the following:

- An alternative name and year to be analyzed are selected ①.
- Release point and point of observation are selected ②.
- A histogram of survival between release and river segment is illustrated ③.

Survival histogram

A survival histogram is opened using the Histogram button on the analysis Tool

Fig. 28. Survival histogram

The analysis tool histogram plots a histogram of survivals statistical information on survival and travel time.:

- Survival statistical properties ❶.
- Statistical properties of travel time ❷.
- Histogram of survival between release and river segment ❸.

Installation and Start-up

CRiSP.1 has four basic files that can be put in a directory in the users home directory. The file manager configuration below (Fig. 29) has these files in the directory crisp_dir

Fig. 29. File manager directory showing essential files for CRiSP.1

Basic files

- all.base.data - a default parameter file that can be read into the model using the I/O tool.
- columbia.desc - defines the river segments, locations of dams, and release sites.
- summary.dat - contains rudimentary results from the last model run.
- crisp1 - the model executable code.

NOTE: Double clicking the left mouse button on crisp1 starts the model.

Parameter files

Using the I/O tool special groupings of files can be made and stored. An example of how these files might be named are illustrated by the file manager shown in Fig. 30.T

columbia.desc

[illegible]

all.base.dat

Fig. 30. File manager with special user defined files

Fig. 30. File manager with special user defined files

```
release_site Asotin
latlon 46 10 00 N 116 56 00 W
end (Asotin)
```

```
river Columbia
flow_max 280.00
```

```
reach Columbia Gorge
volume 24611400000.0
surface_area 888624000.0
latlon 45 38 00 N 122 47 00 W
latlon 45 35 00 N 122 05 00 W
latlon 45 38 00 N 121 57 00 W
end (Columbia Gorge)
```

```
dam Bonneville Dam
latlon 45 38 00 N 121 57 00 W
end (Bonneville)
```

```
reach Bonneville Pool
volume 24611400000.0
surface_area 888624000.0
latlon 45 38 00 N 121 57 00 W
latlon 45 36 00 N 121 07 00 W
end (Bonneville)
```

Fig. 32. Section of columbia.desc that defines river

summary.dat

This file contains a summary of survival information from a model run. Information contains survival information for each release site and for all releases.

Mon Dec 9 15:13:19 1991

Scenario Mode

Release: Lower Granite Hatchery

Species: Chinook 0

Survival Below Estuary

Released: 1000

Passed: 195

Transported In: 0

Censored: 0

Survival: 19.5%

stats 94 150 195.39 112.96 112.50 112.00 2.44

Summary for all Releases

Released: 1000

Passed: 195

Transported In: 0

Censored: 0

Survival: 19.5%

Fig. 33. summary.dat file created after each model run

Data includes:

- Number released
- Number passing to specified points in river system
- Number transported
- Number censored, that is fish that did not leave the system by the end of season
- Percent survival to lowest point in system
- statistics including: First and last passage days; average number passing; mean, median mode and standard deviation of passage days between points.

.name.dat

These files contain information for specific subgroupings of data. Any data convention can be used to identify them. The following are suggested:

- all.name.dat: name convention for files that contain all data,
- beha.name.dat: name of files that contain data stored with behavior menu,
- dam.name.dat: name of files that contain data stored with dam menu,
- flow.name.dat: name of files that contain data stored with flow menu,
- rels.name.dat: name of files that contain data stored with release menu,
- reserv.name.dat: name of files that contain data stored with reservoir menu,
- spil.name.dat: name of files that contain data stored with spill menu.

The designator name could relate to a particular model scenario or date of run.

Theory Manual

Model Computation Diagram

The CRiSP model calculates changes in fish numbers as fish move through tributaries, reservoirs, and dams. The computations accounting for inputs and losses of fish can be diagrammed in terms of a computational tree (Fig. 34). The shaded boxes represent fish numbers input to the system and passing dams and reservoirs on a daily basis. Unshaded square boxes represent calculations of variables which affect travel time and survival of fish through the reservoirs. Rounded boxes represent input data.

Fig. 34. Diagram of model elements

Reservoir Activities

Reservoir mortality is a function of fish travel time. Fish enter a pool from the preceding dam tailrace on a daily basis. Travel time through a pool depends upon daily river flow and fish behavior. Mortality rates are determined by predator activity and nitrogen supersaturation (Fig. 35).

Fig. 35. Elements involved with pool migration and mortality

Flow-elevation

The river velocity is related to river flow and pool depth. The model accounts for a change in pool volume resulting from the sloping nature of the pool. The equation at this time accounts for the slope of the bottom along the river axis (Fig. 36). More realistic relationships will be added later. The geometry used to calculate pool volume and velocity properties are expressed in the equation below:

$$V_f = \frac{W}{F} \left(\frac{H - h + \frac{h^2}{4H}}{1 - \frac{h}{2H}} \right) \quad (1)$$

and:

$$\text{Volume} = WL \left(H - h + \frac{h^2}{4H} \right) \quad (2)$$

where

- H is the average depth of the pool
- H_0 is maximum depth, Here we assume $H_0 = 2H$.
- L is the pool length
- h is the distance below full pool of the water level.
- W is pool width
- F is flow in kcfs

Although this relationship assumes a triangle form for the pool it does, to a first order, describe how average velocity and pool volume change with h .

Fig. 36. Simple pool geometry for volume and flow calculations.

The relationship between pool elevation and volume has been determined by the Army Corps. For Lower granite Pool this is compared to a result using Eq(2) (Fig. 38).

Fig. 37. Pool volume vs. elevation for Lower Granite Pool.

The movement of fish through river segments depends upon flow, swimming behavior, and variance in the migration velocity from all sources and the percent of time fish are available to move with the flow or drift time. The basic equation is

$$\frac{dx}{dt} = (V_f + V_b) D_t + V_{var} \quad (3)$$

where:

- V_f and V_b are flow and swimming behavior velocities,
- V_{var} is the variance in the velocity, and
- D_t is the drift time which is fraction of the day that the fish is available to move with the flow.

The above equation is a stochastic differential equation from which the probability of a fish being in a river segment of length L at time t is given by:

$$p_m(L, t) = \frac{1}{\sqrt{2\pi V_{var} t}} \int_0^L e^{-(x - D_t(V_f + V_b)t)^2 / (2V_{var}t)} dx \quad (4)$$

This equation is used to define the passage of fish between river segments and between dams. All parameters can vary on a daily basis. Description and calibration issues for this travel time model are given in Appendix 1.

Reservoir survival

Mortality of fish in reservoirs from the combined effects of predator density, temperature and nitrogen supersaturation is expressed:

$$\frac{dS}{dt} = -(M_p + M_n) S \quad (5)$$

where:

- M_p is the mortality rate from predation with units of time^{-1} .
- M_n is the mortality rate from nitrogen supersaturation with units of time^{-1} .
- S is the number of smolts leaving a reservoir per day ($\text{smolts reservoir}^{-1}$)

The equation assumes that spill mortality and predation mortality do not interact. The theoretical interaction between the two elements of mortality has not been developed. Initial experiments by ODF&W suggest that squawfish will preferentially attack weak smolts over strong ones. Thus, the mortality equation would tend to overestimate mortality if all other given factors are equal.

Predation mortality

The predation rate depends on predator density and activity. In this model we use equations developed by ODF&W and reported in "Predation by Resident Fish on Juvenile Salmonids in John Day Reservoir 1983-1986", volume 1, The feeding activity increases with temperature and can be described by as an exponential function.

Feeding activity vs. temperature

In the reservoir proper the form of the equation is:

$$M_p = ae^{uT}P \quad (6)$$

where:

- P is predator density in a river segment, default 150, predators km^{-2} .
- T is temperature in degree centigrade, this changes over season.
- $a > 0$, a predator activity parameter depending upon prey species, default value 3×10^{-5} , $\text{km}^2 \text{ predator}^{-1} \text{ day}^{-1}$. This parameter has deterministic and stochastic parts. The stochastic part varies with a uniform random distribution.
- $u > 0$, a predator activity exponent independent of prey species, default value 0.06, $1/\text{deg centigrade}$. Assume this parameter has a deterministic part only.

This temperature equation is based upon temperature studies of squawfish consumption by Vigg and Burley, 1990. "Temperature dependent maximum daily consumption of juvenile salmonids by northern squawfish (*Ptychocheilus oregonensis*) from the Columbia River." Can. J. Fish. Aquat. Res. 47.

Predation density dependence

The equation for predation does not assume a density dependence other than what is expressed by Eq(5). This differs from the assumptions used in CREM (Bledsoe et al 1990) in which an exponential sigmoid function for predation rate is given as:

$$\text{Rate} = \frac{C}{1 + a \cdot \exp(bS)} \quad (7)$$

where:

- C = maximum rate 3.9 smolts $\text{predator}^{-1} \text{ d}^{-1}$
- $a = 10.951$ a coefficient
- $b = -0.000618$ a coefficient

By comparison, our rate expression is linear and from Eq(5) is:

$$\text{Rate} = M_p S \quad (8)$$

where M_p depends on temperature and predator density according to Eq(6). To evaluate if a linear or sigmoid equation can be used we plotted both equations for predation data in July and August in Fig. 38. The statistics of the two equations are illustrated in Table 2: (Reference Peterson, Mesa, Hall-Griswold, Schrader, Short and Poe 1990. Magnitude and dynamics of predation on juvenile salmonids in Columbia and Snake River Reservoirs, Annual Report of Research, 1989-1990.)

Fig. 38. Comparison of linear and sigmoid consumption equations.

Table 1: Comparison of sigmoid and linear rate models.

Statistic	Sigmoid	Linear
coefficients	C = 3.9 a = 10.95 b = -0.000618	slope = 0.0005176
std error	C = 0.66 a = 4.83 b = 0.00019	slope = 0.000042
t statistic	10.6678	12.2519
# points	32	24
df	3, 29	1, 23
F-statistic	41.6	150.11
r-squared		0.8671
p	< 0.001	

The important point here is that a linear model also fits the data and so we apply a linear density dependence as described by Eq(5).

Calibration of predation rate

A calibration of the rate coefficients for Eq(5) was approached in two ways. The coefficients for the boat restricted zone in the tailrace of John Day Dam can be estimated from the studies of ODF&W. In addition the coefficients can be estimated by fitting Sims and Ossiander data and NMFS flow survival, travel time, flow data.

To calibrate consumption with the ODF&W data data into spring (April and May) (Fig. 40) and summer (July and August) (Fig. 40) since temperatures are different in the two periods.

Fig. 39. Smolt consumption rate as a function of smolt density in spring.

Fig. 40. Smolt consumption rate as a function of smolt density in summer.

The regressions statistics for these two data sets are illustrated in Table 2:

Table 2: Regression of ODF&W consumption rate data^a.

Statistic	Spring	Summer
slope	0.0002840	0.0005176
slope std error	0.000027	0.000042
t statistic	10.6678	12.2519
# data points	21	24
F-statistic	113.80	150.11
r-squared	0.8505	0.8671
Temperature ^b	10° 3 C ^c	20° C ^d
a ^e	0.000078	0.0000426
a	0.00016	
u	0.058	

a. "Predation by Resident Fish on Juvenile Salmonids in John Day Reservoir 1983-1986", volume 1, page 189. Plus Peterson, Mesa, Hall-Griswold, Schrader. Short and Poe 1990.

b. April May average 1983-1986 McNary Dam

c. April May average 1983-1986 McNary Dam

d. July-Aug average 1983-1986 McNary Dam

e. assuming $u = 0.061$

The coefficient a can also be estimated by fitting the Sims and Ossiander survival and travel time data to the model. The resulting calibration is illustrated in Fig. 41 and Fig. 42.

Fig. 41. Flow survival data calibrated with Sims and Ossiander data.

Fig. 42. Mortality per mile vs. flow from Sims and Ossiander data.

These two methods of calibration provide independent checks on each other. The differences are illustrated in the Table 3: below. The important point is that ODF&W data produces a predator density that is about a factor of 10 larger than was obtained with the

Sims and Ossisnder data. Several possibilities exist for this discrepancy. One possibility is that the predation rate per predator in the tailrace is about a factor of 12 larger than in the reservoir proper. This is certainly possible if the smolts exiting through the tailrace are disorientated and are not as able to avoid predation as wellas smolts in the reservoir. From this analysis it appears that any model that applies rate coefficients from the tailrace and estimated densities in the reservoir probably over estaimte the predation rate in the reservoir. I believe this mabe be the case with CREM.

Table 3: Predation rate coefficients in model.

parameter	S & O	ODF&W
a	11×10^{-6}	153×10^{-6}
u	0.06	0.058
Pred density	410	410
rate @ 10° C	0.0082	0.112

Supersaturation mortality

Mortality due to gas bubble disease associated with nitrogen supersaturation depends on the depth of the fish, vitality, exposure time and nitrogen supersaturation levels. Results of laboratory studies indicate a reproducible relationship over time and at different levels of supersaturation. Using the work of Dawley et al (1979) and plotting mortality after one hundred days of exposure we obtain the mortality ate in terms of percent loss per day shown in Fig. 43 curve A. Using mortality rates after 40 days of exposure generates lined B.

Fig. 43. Percent mortality rate of juvenile autumn chinook as a function of saturation. Curve A gives mortality after 100 days exposure. Curve B shows mortality after 40 days of exposre. Data from Dawley et al. 1979.

An equation describing the morality rate depends on what mortality line is used. If a continuous mortality process is used then line A is more representative and an equation for the relationship is:

$$M_n = be^{vN} \quad (9)$$

where:

- N is percent saturation *above* 100%.
- $b > 0$, a species specific gas bubble disease rate with a value of 0.00647 day^{-1} , Assume b has deterministic and stochastic parts where the stochastic part varies with a uniform random distribution.
- $v > 0$, a species specific parameter, default value for graph 0.202 N^{-1} , Assume v is deterministic only.

If curve B is assumed as relevant a two part curve can be applied with a threshold value. The equation in this case is:

$$\begin{aligned} M_n &= 0 & \text{if} & \quad S \leq S_{crit} \\ M_n &= a(S - S_{crit}) & \text{if} & \quad S > S_{crit} \end{aligned} \quad (10)$$

where for fall chinook as illustrated in Fig. 43

- $a = 0.312 \text{ day}^{-1}$
- $S_{crit} = 20$

Nitrogen from spill

The equation for the production of nitrogen supersaturation in spill can be estimated with mechanistic and empirical equations. An empirical equation based on a hyperbolic function has no underlying theory and simply fits some supersaturation vs. spill curves. A mechanistic theory developed by WRE (1971) and reviewed by Boyer (1974) developed nitrogen levels in terms of they physical processes producing spill. It requires a number of geometric and physical parameters. Here we discuss both equations.

Exponential equation

Hyperbolic spill equation is of the form:

$$N_s = bF_s + a(1 - e^{-kF_s}) \quad (11)$$

where:

- N_s is the percent supersaturation above 100%,
- F_s is the spill flow in kcfs and
- a , b and k are coefficients specific to each dam and fit from sill flow supersaturation data.

In this model can also be interpreted in terms of a nitrogen concentration as is used in the mechanistic model.

Mechanistic equation

Equation describing nitrogen in mg./l takes the basic form:

$$N_s = N_{eq} \cdot \bar{P} - (N_{eq} \cdot \bar{P} - N_{fb}) \cdot \exp\left(-\frac{K_e}{F_s} WL\Delta\right) \quad (12)$$

where:

- F_s is spill in kcfs
- N_s is nitrogen concentration in tailrace in mg./l
- N_{fb} is the nitrogen concentration in the forebay in mg./l
- N_{eq} is nitrogen equilibrium concentration as a function of temperature at one atmospheric pressure can be approximated by the equation:

$$N_{eq} = 21.1 - 0.3125 \cdot T \quad (13)$$

- L is the length of the spilling basin in feet.
- P is average hydrostatic pressure in the main flow in the spilling basin in atmospheres and is defined:

$$\bar{P} = P_0 + \frac{\alpha c}{2} (D_s - Y_0) + \frac{\alpha}{4} (D_s + Y_0) \quad (14)$$

where P_0 is barometric pressure at the site in atmosphere. We assume $P_0 = 1$.

- α density of water $\alpha = 0.0295$ atm./ft
- c is dimensionless dam dependent parameter describing the aeration of the roller at the base of the spill (See table 1 for values).
- W is spillway width (See table 1 for values)
- D is water depth at end of spilling basin (See table 1 for values)
- Y_0 is the thickness of the spill at entrance to spilling basin

$$Y_0 = \frac{F_s}{W\sqrt{2gH}} \quad (15)$$

where H is the hydraulic head expressing the forebay elevation minus the bottom of the spilling basin. H is in ft and gravity constant is $g = 32$ ft/s²

- D_s is a differential pressure factor defined:

$$\Delta = \left(\bar{P} + \frac{\alpha}{4} D_s + Y_0\right)^{1/3} - \left(\bar{P} - \frac{\alpha}{4} D_s + Y_0\right)^{1/3} \quad (16)$$

- K_e is a bubble entrainment coefficient with units of ft s⁻¹ atm.^{-1/3} and is defined:

$$K_e = aE^b (1.028)^{(T-20)} \quad (17)$$

where T is temperature in degrees C, a and b are dam specific constants (Table 1) and E energy loss rate defined:

$$E = \frac{\text{total headloss}}{\text{residence time}} = \frac{F_s}{LWD_s} (H - D_s) - \left(\frac{F_s}{WD_s} \right)^3 \frac{1}{2gL} \quad (18)$$

Nitrogen in tailrace

Nitrogen concentration in the tailrace of a dam is the result of mixing of spill water and water passing through turbines. The equation is:

$$N = N_{fb} + \frac{F_s}{F} (N_s - N_{fb}) \quad (19)$$

where

- F is total flow through the dam in kcfs
- F_s is spill flow in kcfs
- N_{fb} is the forebay nitrogen level in either concentration or percent above saturation
- N_s is spill nitrogen level in either concentration or percent above saturation

Nitrogen at Confluence

The nitrogen at a confluence is determined by the addition of two flows with different nitrogen levels the equation is:

$$N = \frac{F_1 N_1 + F_2 N_2}{F_1 + F_2} \quad (20)$$

where F designates flow in kcfs N the nitrogen concentrations and subscripts designate the segments of the confluence.

Nitrogen dissipation

Nitrogen levels above the saturation level are lost from the river as a first order process. To develop this define a total flux equation for a segment as (WRE, 1971 p77)

$$\Phi = AK_d (N_{eq} - N) \quad (21)$$

where

- Φ is the flux of nitrogen across the air water interface of a reservoir or river segment,
- N is the nitrogen supersaturation concentration in the segment,
- N_{eq} is the nitrogen equilibrium concentration,
- A is the surface area of the segment and
- K_d is the transfer coefficient which is defined:

$$K_d = \left(\frac{D_m U}{D} \right)^{0.5} \quad (22)$$

where

- D_m is the molecular diffusion coefficient of nitrogen and is dependent on factors such as temperature.
- U is a hydraulic stream velocity
- D is a depth of segment

To express the loss in terms of concentration we divided Eq(21) by AD to give:

$$\frac{dN}{dt} = \frac{\Phi}{AD} = \left(\frac{D_m U}{D^3} \right)^{0.5} (N_{eq} - N) \quad (23)$$

To put the calculation in units of miles and days note one mile = 16.0934×10^4 cm = 5280 ft, one day = 8.64×10^4 seconds. Now expressing U in miles/day and D in feet and D_m in cm^2/s the diffusion coefficient is per unit square mile of river is

$$\frac{dN}{dt} = k (N_{eq} - N) \quad (24)$$

where the coefficient k is expressed:

$$k = 700.75 \left(\frac{D_m U}{D^3} \right)^{0.5} \quad (25)$$

where assuming:

- D_m is order of $2 \times 10^{-5} \text{ cm}^2/\text{s}$ (Reference Hand Book of Chemistry and Physics)
- U order of 20 miles/day
- D order of 30 ft.
- then $k = 0.085 \text{ day}^{-1}$.

Now the loss rate due to degassing can be expressed as a function of time since the water entered the tailrace by the equation:

$$N(t) = N_{eq} + [N(0) - N_{eq}] e^{-kt} \quad (26)$$

where

- N_{eq} is nitrogen equilibrium concentration defined by Eq(13)
- N is the tailrace concentration defined by Eq(19)
- k is the dissipation coefficient defined by Eq(25) or set to a constant.

For the empirical model of supersaturation we can assume that N is in terms of percent above supersaturation and then set $N_{eq} = 0$.

Stochastic processes

There are variations in both rate terms for predator and nitrogen related mortality. Questions of how to express this variability is difficult to answer. The approach here is to express deterministic and stochastic variability

- between fish species,
- between fish releases,

- between river segments,
- between times.

Deterministic variations are expressed in three forms:

- for predator mortality, deterministic variations between river segments are expressed by predator density in each segment P ,
- for predator mortality, deterministic variations in time are expressed in terms of daily river temperature T ,
- for supersaturation related mortality, deterministic variations in time and river segment are expressed in terms of daily spill flow at each project F .

Stochastic, or random variations, are described via the rate coefficients themselves. The underlying idea is that the rate terms are by their very nature variable. These stochastic variations are included as linear terms in the rate processes a and b of Eq(6) and Eq(9). The equations are

$$\begin{aligned} a &= \bar{a} + a' \\ b &= \bar{b} + b' \end{aligned} \quad (27)$$

where $\bar{a}$ and $\bar{b}$ are the mean values of the rate coefficients and a' and b' are the stochastic elements. The stochastic elements are allowed to vary from segment to segment and from one release to the next. They are also specific to each species.

The combined stochastic rate equation now is

$$\frac{dS}{dt} = - (\bar{a} + a') e^{uT} P S - (\bar{b} + b') (cf^w)^v S \quad (28)$$

where:

- $\bar{T}$ is average temperature over residence time in river segment
- P is predator density specific to the river segment
- f is the percent of flow to spill on time t
- a is a species specific predation rate parameter
- b is species specific supersaturation mortality rate parameter
- a' and b' are species specific stochastic rate parameters that vary over segments and release and are described by probability density functions
- u is a coefficient for temperature on predator activity and is fixed for each run
- v is a species specific saturation mortality exponent and is fixed for each run
- c and w are segment specific parameters relating the development of supersaturation
- z is a gas dissipation parameter fixed for all river segments.

Stochastic term probability density

Variation in the stochastic rate parameters are described by probability density functions (pdf). We require that variations in coefficients be positive. Although many functions are possible we apply a simple function based upon a uniform probability distribution. In this case a random sample of a rate parameter is obtained from the equation:

$$U = a + bR \quad (29)$$

where R is a random variate unit rectangular distribution between 0 and 1. The factors a and b are obtained from the mean m and coefficient of variation cv of the distribution using:

$$a = m \cdot (1 - cv\sqrt{3}) \quad b = m \cdot cv \cdot \sqrt{12} \quad (30)$$

Dam passage

Fish pass a dam through spill, turbines or bypass systems (Fig. 44). Fish in a forebay that are not spilled either go through a turbine or are guided via a traveling screen toward a bypass facility. There they are collected and either transported or released into the tailrace. A diel passage distribution defines the probability that fish will pass a dam on an interval of time, usually 2 to 6 hours. The model also allows for predation in the forebay while fish are waiting to pass. All fish passage probabilities and mortalities are defined with deterministic and stochastic parts rate processes. The stochastic parts are sampled with a truncated normal distributions.

The equation for turbine survival can be expressed

$$N_{turbine} = N_{forebay} \cdot p_{pass} \cdot (1 - m_{forebay}) \cdot (1 - m_{turbine}) \cdot (1 - fge) \cdot (1 - aSF) \quad (31)$$

where:

- $N_{turbine}$ is the number of fish passing in a time increment (2 to 3 hours),
- $N_{forebay}$ is the number of fish in the forebay ready to pass in the increment,
- p_{pass} is the probability of passing over the increment,
- $m_{forebay}$ is mortality in the forebay over the increment, this depends on predator density, temperature, time of day and residence time of smolts in forebay.
- $m_{turbine}$ is the mortality in turbine passage,
- fge is the fish guidance efficiency for either a day or night period,
- a is a spill efficiency coefficient,
- S is the percent spill in the increment, and
- F is the flow in kcfs.

The equation for bypass survival without spill can be expressed

$$N_{turbine} = N_{forebay} \cdot p_{pass} \cdot (1 - m_{forebay}) \cdot (1 - m_{bypass}) \cdot fge \cdot (1 - aSF) \quad (32)$$

where:

- m_{bypass} is mortality in the bypass.

The equation for transport survival can be expressed

$$N_{turbine} = N_{forebay} \cdot p_{pass} \cdot (1 - m_{forebay}) \cdot (1 - m_{transport}) \cdot fge \cdot (1 - aSF) \quad (33)$$

where:

- $m_{\text{transport}}$ is mortality in the transport.

The equation for spill survival can be expressed

$$N_{\text{turbine}} = N_{\text{forbay}} \cdot p_{\text{pass}} \cdot (1 - m_{\text{spill}}) \cdot aSF \quad (34)$$

where:

- m_{spill} is mortality in the spill passage.

The equation for spill survival can be expressed

$$N_{\text{turbine}} = N_{\text{forbay}} \cdot p_{\text{pass}} \cdot (1 - m_{\text{spill}}) \cdot aSF \quad (35)$$

where:

- m_{spill} is mortality in the spill passage.

Fig. 43. Dam passage module

PASSAGE ANALYSIS MODEL: A SPREADSHEET MODEL OF JUVENILE FISH PASSAGE IN THE COLUMBIA RIVER

Introduction

The Passage Analysis Model (PAM) is designed to aid decision making regarding actions that might affect the survival of juvenile salmon and steelhead outmigrating through the Snake and Columbia rivers. The model works in conjunction with the Systems Analysis Model (SAM) which acts as a hydroregulator for PAM. SAM provides a 50 year record of flow in the Snake and Columbia under a hypothesized regulation of the hydroelectric system. Using this regulation and a variety of inputs regarding operation of the dams and fish passage measures, PAM generates a survival rate estimate for the time period represented by the SAM input. PAM also provides water travel time, survival at different points in the migration, and transportation benefits. The model will also work with a single flow input to provide a detailed analysis of passage conditions. PAM can produce an output file that can be used by the System Planning Model to provide a life cycle analysis of passage alternatives.

Description of Disk Files

The Passage Analysis Model is on the distribution disk in the subdirectory \PAM. Four files are present in this subdirectory, including PAM.WQ1 (Quattro PRO format), PAM.WK1 (Lotus format), and PAM.XLS (Excel format). Also included is a Quattro file, FLOW.WQ1 which provides a default flow set for PAM. To utilize the model, you must have one of the three spreadsheet packages listed above. To start the model, simply copy the file of your choice into the directory on your harddisk that you will be using and load the file into your spreadsheet program.

Description of PAM operation

PAM was developed using Quattro PRO¹ spreadsheet software, and takes advantage of some of the special features of this package. The model works in two modes. The single flow input mode provides survival and other passage parameters at a single flow, and a set of defined project operational conditions. The multiple flow mode uses Quattro's "What-if" or sensitivity analysis feature to provide flow input for a series of years and calculates survival and other passage parameters for each year. The spreadsheet is divided into two sections (Figure 1) that are linked through the sensitivity analysis feature. In Figure 1, the area within the dotted lines applies to the multiple flow input mode. This usually consists of 50 years of flow for a single month (or other time

¹ Version 3.0 from Borland International Incorporated

Figure 1. Diagrammatic Representation of PAM Spreadsheet.

period) from SAM. The output for the multiple year run can be defined as a subset of the outputs from the single flow output section. Output in the multiple flow mode is printed to the immediate right of the flow input. The left section of the spreadsheet is the calculator of passage survival rate and other parameters. The two sides are linked through the flow input cells.

The left section of the model is divided into two portions. The top of the spreadsheet is the portion that is normally viewed and worked with. This contains the input area, with the exception of multiple flow inputs as noted above, and the model output when operating in single flow input mode. Printing this area provides a record of the input and output of a particular run. The area below this input and output area is the calculation section where survival of fish passing through the eight projects is tracked. This is normally not viewed and useful outputs from each dam are transferred to the output portion of the upper sections.

PAM Input

With the exception of the multiple flows, input occurs in two tables. The top table contains the non-project specific inputs. This includes the parameters for the calculation of reservoir mortality rate and the survival through bypass systems and spillways which are not considered as project specific. Also included is the instantaneous spill cap. This relates to the diel passage feature which will be explained below. Flow in the Snake and Columbia is also input in this top table. When the multiple year input feature is toggled on, these cells are not available for input and link to the flows input to the right as shown in Figure 1. Reservoir mortality rate per mile is calculated and shown in this table given the choice of flow/reservoir models and the given flow.

The second table in the model provides the project specific inputs. These specify powerhouse passage conditions, how smolt transportation is governed, how spill is to be managed, and the elevations at which each reservoir will be held. The number of fish to be put through the model above each project is also provided at this point. Fish inputs can occur above each of the eight model projects. Table 1 lists the inputs for the model.

PAM is generalized for nine projects. This allows the model to be parameterized for either the Snake or mid-Columbia reaches. The configuration of projects is set up by use of the project toggles in the project inputs table. Project one must always be on and no toggle is available.

Table 1. PAM input fields.

Input Name	Project Specific	Description
Snake River High flow intercept	no	Reservoir mortality Y intercept for flows above critical flow.
Snake River High flow slope	no	Reservoir mortality slope for flows above critical flow.
Snake River Critical flow	no	Critical flow level for break in flow /survival relation.

Snake River Low flow intercept	no	Reservoir mortality Y intercept for flows less than critical level.
Columbia High flow intercept	no	Reservoir mortality Y intercept for flows above critical level
Columbia High flow slope	no	Reservoir mortality slope for flows above critical level.
Columbia Critical Flow	no	Critical flow level for break in flow/survival relation
Columbia Low flow intercept	no	Reservoir mortality slope for flows above critical level
Exponential: Snake A Factor	no	Factor for equation of the form $Y = A \exp^{-BX}$ for relation between flow (X) and reservoir mortality rate per mile (Y)
Exponential: Snake B Factor	no	Op Cit.
Exponential: Columbia A Factor	no	Op Cit.
Exponential: Columbia B Factor	no	Op Cit.
Polynomial Snake A Factor	no	Factor for equation of the form $Y = A + BX + CX^2$ for relation between flow (X) and reservoir mortality rate per mile (Y)
Polynomial Snake B Factor	no	Op Cit
Polynomial Snake C Factor	no	Op Cit
Columbia Snake A Factor	no	Op Cit
Columbia Snake A Factor	no	Op Cit
Snake Cutoff KCFS	no	The flow value that defines the maximum nitrogen effect of the polynomial curve
Columbia Cutoff KCFS	no	Op.Cit
Columbia Snake A Factor	no	Op Cit
Snake R. Flow	no	Flow in kcfs. Single Input = flow input for single estimate, Multiple Input = input point for flow from SAM (no input here), TT EQ = Flow equivalent at reservoir elevations other than average normal.
Columbia R. Flow	no	Op cit.
Use multiple flows?	no	Toggle for manual or multiple flow input
Flow Model	no	Specifies flow model. B = broken stick, E = exponential, P = polynomial
Reservoir mortality rate Adjuster	no	Multiplier on calculated reservoir mortality rate. Moves function vertically e.g. to simulate predator control or uncertainty.
% Snake R. Reservoir mort /mile	no	Calculated mortality rate (not input).
% Columbia R. Reservoir mort/mile	no	Calculated mortality rate (not input).
Bypass Survival	no	Survival rate in bypass system.
Spillway Survival	no	Survival rate over spillway.
Instantaneous spill cap	no	Cap on spill at any time.
FGE (Fish Guiding Efficiency)	yes	Proportion of fish approaching powerhouse diverted into bypass.
Turbine Survival	yes	Survival rate of fish passing through the turbines.
Proj Tog	yes	Turns on desired project 2-9. Project 1 always on

TRIG Flow	yes	Flow below which all collected fish are transported.
SEPRTN OVRLP	yes	Proportion of overlap between transported and non-transported fish (1-separator efficiency).
TRSPT Surv	yes	Effective survival rate of transported fish relative to passage survival of non-transported fish.
PROP TRSPD	yes	Proportion of fish in the collection that are transported. Calculated based on TRIG flow and SEPRTN OVRLP (no input).
TBR Adjustment	no	Standardizes transport survival based on assumed TBR
Daily Fixed Spill	yes	Base daily average spill. Instantaneous spill = Daily fixed spill/ spill period. Model will spill this until powerhouse capacity is reached. After this, whichever is greater.
Spill Period	yes	Proportion of day when spill will be maximized up to instantaneous spill cap (see above)
PROP Fish Passing	yes	Proportion of daily fish migration passing during spill period.
PWRHS Capacity	yes	Powerhouse flow capacity in kcfs
RESV Length	yes	Reservoir length in miles
Project Storage: Actual	yes	Desired storage in reservoirs in maf.
Project Storage: Normal Full	yes	Reference point for reservoir storage. Normal full storage from Corps.
Fish Input	yes	Number of fish entering system above the dam.

PAM Output

The results section contains output from each project as well as the total migration. Transported and non-transported fish are tracked separately. Output occurs in two places depending on whether a single flow is used for a detailed one time calculation of survival or through the multiple flow input feature. When using the latter, QUATTRO only provides a subset of the output which can be defined by the user. This is placed immediately adjacent to the 50 year record of flow. (Figure 1). Table 2 lists the outputs and their locations.

Table 2. PAM output parameters.

Output Parameter	Project Specific	Multiple flow feature	Description
NTRSPD Dam Survival	Yes	No	Survival rate at each dam for fish that are not transported.
RESV SURVL	Yes	No	Survival rate in each reservoir
NTRSPD Proj SURVL	Yes	No	Product of previous dam and reservoir survival for each project
NTRSPD SURVL TO BON	Yes	No	Survival rate of non transported fish to below Bonneville Dam.

Total SURVL to BON	Yes	No	Survival of all fish including transported fish to below Bonneville Dam.
Daily Spill	Yes	No	Amount of flow spilled.
TRVL Time	Yes	No	Water travel time in days through each pool.
TURB MORTS	Yes	No	Number of fish killed in turbines for each project.
MIGRNT SURVS	Yes	No	Number of fish surviving below each project and continuing migration.
TRSPD Survs	Yes	No	Number of fish transported after applying the effective transport survival rate
Average Spill	No	No	Average spill at all eight projects.
Total Survival to below Bonneville	No	Yes	Survival rate of fish passing all eight projects including transported fish.
Total loss rate to turbines	No	No	Proportion of starting population lost to turbine passage.
Survival rate of non-trspd migrants	No	Yes	Survival rate through all eight projects
TBR from Lower Granite Tailrace	Yes	Yes	Realized transport benefit ratio measured at the Lower Granite tailrace.
TBR from Little Goose Tailrace	Yes	No	Op cit. from Little Goose tailrace
TBR from McNary Tailrace	Yes	No	Op cit. from McNary tailrace
Snake River travel time	No	No	Water travel time from Lewiston to Ice Harbor tailrace in days.
Columbia travel time	No	No	Op cit. from Ice Harbor tailrace to below Bonneville in days
Total travel time	No	Yes	Sum of previous travel times.

Special features of PAM.

PAM output.

Each time PAM calculates, it analyzes juvenile fish passage for a single flow and population input. In other words, if the flow inputs consist of average May flow, the passage analysis will refer to the average condition during this period.

Multiple Flow Input Feature.

Using Quattro's "What if" feature, PAM can quickly analyze passage conditions for an extended flow record. For example, SAM can provide a list of 50 estimates of flow at The Dalles and Lower Granite for the month of May given a certain scenario for operation of the hydroelectric system. PAM will then use this list of flows to provide 50 estimates of survival and other passage parameters. This can be used to compare the biological impacts of managing the hydroelectric system in different ways.

Flow affects the model in several ways meaning that different parameters vary between years. These are as follows:

- Reservoir mortality rate per mile.
- Proportion of Snake flow to Columbia flow.
- Proportion of fish transported (e.g. currently set to FTOT guidelines).
- Spill at each project.

Although Quattro's "What-if" feature is very powerful, it does have a major limitation: only one value can be substituted in the spreadsheet at a time¹. In other words, only a single list of flow for one project, say 50 years of May flow at The Dalles, could be analyzed. Flow in the Snake in this case would have to be a constant proportion of flow in the Columbia. However, an important aspect of different flow alternatives is how they will affect flow in the Snake which may have a minor impact on flow in the Columbia. In any event, flow in the Snake does not track flow in the Columbia exactly and many years of relatively good flow in the Columbia have occurred when flow in the Snake was low. For these reasons, it was important to be able to substitute two inputs each year for flow in the Snake and the Columbia.

To do this, the two desired flow levels were combined into one number containing both pieces of information. This value was then used by the "What-if" feature in Quattro. The substituted factor was dissected each time and the two individual pieces of information placed in the flow input cells in the left portion of the spreadsheet. For example, say flow in the Snake in year one was 60 kcfs and flow in the Columbia was 200 kcfs. Flow in the Snake was multiplied by 1,000 and added to the flow in the Columbia with the result of 60,200. The "What-if" feature would take this figure and place it in a cell called the Flow Seed for each of the 50 years. The Flow Seed is the link between the two halves of the spreadsheet and is used in the left portion of the spreadsheet in the cells for multiple flow input. In the Snake River flow cell, the integer portion of the 60,200 Flow Seed divided by 1,000 was taken, resulting in value of 60. This value times 1,000 (60,000) was subtracted from the Flow Seed in the Columbia flow cell to provide the Columbia flow of 200. Thus, the single factor Quattro "What-if" feature was fooled into substituting two values each year.

Reservoir Mortality Rate per Mile.

The current version of PAM offers three alternatives for calculating reservoir mortality rate per mile in response to flow. All are based on the Sims and Ossiander (1981) system survival data as developed by AMWG (McConnaha, 1989), and describe the effect of flow (or velocity) on reservoir mortality as decreasing as flow increases. This implies that reservoir mortality may have flow dependant and flow independent components. At low flows the flow dependant component is dominant. At higher flows the flow independent component becomes increasingly important and may form a more or less constant basement at very high flows.

Exponential.

The exponential model has been used by the fishery agencies and tribes (CBFWA, 1991) to describe the relation between flow and reservoir survival (Figure 2). The parameters presently used are those provided in Petrosky and Weber (1990). This

¹ Quattro does have a two variable "What-if" feature but it is not as versatile as the single variable option and would not work in this case.

model describes the relation between flow and reservoir mortality to be one of gradually and smoothly decreasing response with increasing flow. Flow will have the greatest effect on mortality rate at low levels. At high flow, mortality is still decreasing although at a lesser rate.

Alternative Reservoir Mortality Models Available in PAM

Figure 2. Alternative Reservoir Mortality Models Available in PAM.

Broken-Stick.

The broken-stick or threshold model is a two step function that is separated by a defined critical flow level. Below this, mortality increases sharply as flow decreases. Above this critical flow mortality rate decreases at a much reduced rate as flow increases. In PAM, the break in the broken stick model can be specified to examine the effects of alternative assumptions and uncertainty.

Polynomial.

This model was used in the FISHPASS model developed by the Corps and the CRISP.0 derivative used by Bonneville. The polynomial model provides the best mathematical fit to the Sims and Ossiander (1981) data points as developed by AMWG (McConnaha, 1989). This model states that mortality decreases as a function of flow up to some minimum and then increases at higher flows. The only biological explanation for such an increase in mortality at higher flows is nitrogen super-saturation as a result of high spills. This, in fact, probably occurred during the period of time the Sims and Ossiander data were collected because the Snake River projects were incomplete. Proportionately greater amounts of spill occurred than would now at the same flow. In PAM, the increase in mortality is not continued past a specified flow (cutoff). Mortality levels out at higher flows. Inputs used are those in CRISP.0 as specified in BPA (1991).

As shown in Figure 2 the three models as presently parameterized are very similar. The differences can be significant, however, when taken to the power of the total number of miles of reservoir encountered in migration from an upstream location.

The reservoir mortality functions can be moved vertically using the Reservoir Mortality Rate Adjuster. This is a multiplier on the calculated mortality rate. It can be used to look at alternative functions, uncertainty, or to simulate the effect of predator control, for example.

Pool Elevations.

Elevation of the reservoirs behind the dams is an important determinant of water velocity through the pools. Conventionally, elevations have been viewed as fixed and flow has varied to change velocity. Recently, however, proposals have been advanced to lower the elevations of the pools to increase water velocities and decrease fish travel time. Analysis of this feature is available in PAM.

To do this, the model is referenced to the Average Normal pool elevation provided by the Corps of Engineers for each project (COE, 1991). In terms of water velocity, lowering the pools below this is equivalent to providing a certain increase in flow. Using this reasoning, the model simply shifts the flow to adjust for elevation variation from average normal. The new flow is listed as the TT EQ or travel time equivalent flow level in the upper part of the input section. Calculation of the TT EQ is based on simple water displacement equations².

Smolt Transportation.

The model for smolt transportation is provided as a separate document (McConnaha, 1991). In brief, the assumption is made that survival of transported fish is fixed once they are in the barges and is independent of conditions outside the barge that affect survival of non-transported fish. Once the survival of transported fish is estimated, it is fixed for subsequent analysis³. Survival of non-transported fish varies in response to flow or other variables. Thus the Transport Benefit Ratio (TBR) changes in response to flow and the position in the river where transported fish are collected.

The first step in using this rationale is to estimate the survival of fish once they are in the barge. This has been done using the 1986 evaluation of transport by Matthews et al. (1990). They estimated that the benefit of transport in terms of effect on adult production to Little Goose Dam was 1.6:1 in 1986. Using PAM, the estimated survival of non-transported fish in 1986 was 0.2395 from the Little Goose tailrace (exponential reservoir model). To produce an adult return to this point of 1.6:1, the effective survival of transported fish was 1.6×0.2395 or 0.3832. This results in a 2:1 benefit at Lower Granite and a 0.84:1 benefit at McNary in 1986. This transport survival rate has been used then to set the TBR for conditions other than 1986. In the present version of PAM, this standardized transport survival is broken into two components. The transport survival is the direct, observed mortality in the transport barge. The TBR adjustment is

² Recently, the Corps released new calculations for water travel time using the "backwater" method. This is apparently more accurate than the displacement method and may be significantly different. PAM is now being modified to use this new information.

³ This assumption is almost certainly a simplification. The survival of transported fish to adult may be affected by passage prior to collection and fish condition. The generalized transportation model of a floating TBR would continue to hold. However, information on transport survival is extremely limited. Available data is now being combed to analyze this problem.

used to standardize this to an assumed TBR. In the example, if transport survival is set at 0.98, the TBR adjustment would be 0.3941 ($0.3832 / 0.98$).

Diel Passage.

Although PAM estimates survival and other passage parameters for a single flow value, spill within the time frame represented by the flow can be shaped into two periods. In other words, spill can be shaped to account for diel passage within an average day within the time period of the flow. This is done by specifying the portion of the day within which spill will be maximized and the portion of the migration passing during that portion of the day. Daily average spill is input as is the maximum proportion of the flow that can be spilled. Survival is calculated for the spill period and outside the spill period and a weighted average based on the proportion of the migration that will pass in each period is calculated.

For example, say that the daily average spill was 50%. The user specifies that spill will be maximized up to a level of 70% of the flow during a 10 hour period (instantaneous spill cap = 0.70, spill period = $10/24 = 0.42$). During this period 65% of the migration will pass the project (PROP Fish Passing = 0.65). Spill during the spill period would be $0.5/0.42 = 1.19$. This is not only impossible but exceeds the daily spill cap. Spill is then set at 0.70 during the spill period and survival is calculated for 65% of the run at this spill level. The remainder of the spill up to 50% of the daily flow is used to calculate the survival of the remaining 35% of the run.

Use of PAM.

The present version of PAM was developed using the Quattro Pro spreadsheet. As noted above, the model takes advantage of a feature of Quattro that may be unique. As a result, it will presently only run on Quattro using the multiple flow input feature. If it is imported into other spreadsheets as a .WK1 file (Lotus), the left hand or single flow section will work. Future development may seek to find similar features in other packages such as Microsoft Excel.

PAM is shipped in three versions. PAM.WQ1 is the complete version in QUATTRO. PAM:WK1 is a Lotus version translated by QUATTRO, while PAM.XLS is a version that works in Excel. The latter two version use single flow inputs only.

References Cited

- Bonneville Power Administration (BPA), 1991. Columbia River salmon passage (CRISP.0) model documentation. Bonneville Power Administration, May 28, 1991.
- COE, 1991. Water particle travel times at various pool elevations. U.S. Army Corps of Engineers, unpublished memo dated January 9, 1991, submitted to the NW Power Planning Council.

- CBFWA, 1991. The biological and technical justification for the flow proposal of the Columbia Basin Fish and Wildlife Authority. Columbia Basin Fish and Wildlife Authority, February 1991.
- McConnaha, W.E. 1990. Memorandum to monitoring and evaluation work group. Analytical methods work group: Flow/survival relationship. June 11, 1990. Northwest Power Planning Council.
- McConnaha, W. E. 1991. A conceptual model of smolt transportation in the Columbia River. Northwest Power Planning Council, May, 1991.
- Petrosky, C. and Weber, E. 1990. Integrated system plan flow analysis documentation: Spring Chinook, Summer Steelhead. Memo to Fish Passage Advisory Committee, November 29, 1990.
- Sims, C. and F. Ossiander, 1981. Migrations of juvenile chinook salmon and steelhead in the Snake River from 1973 to 1979. National Marine Fisheries Service, Coastal Zone and Estuarine Studies, US Army Corps of Engineers contract no. DACW68-78-C-0038.

04/24/92
W:\cm\ww\PAMDOC.DOC

SECTION 3.7

FLOOD CONTROL WORK GROUP SCREENING PROCESS

INTRODUCTION

The Flood Control Work Group (FCWG) prepared a methodology/model to screen the numerous system operating alternatives in the screening phase of the System Operation Review (SOR). The screening model measures the impact (cost of damages incurred) on flood control capability for each alternative.

ASSUMPTIONS ABOUT THE SCREENING PROCESS

The following assumptions were made by the FCWG regarding the requirements for alternatives:

- River operation simulation experts (ROSE) group used the scenarios to produce regulated flows, elevations, storages, etc. of each alternative with the hydroregulation models on a monthly/half-monthly time increment.
- The 5 years used for screening (1931, 1938, 1940, 1957, and 1956) attempted to represent the full range of flows, but did not depict the shape of a hydrologic frequency curve at any of the seven damage centers (see below).
- No attempt was made to assign risk (probability) to the damages computed. Risk was evaluated using Supertree.
- Estimates of "Maximum" and "Minimum" peak flows and peak elevations for each monthly average flow were based on the professional judgment of the FCWG members. "Maximum" and "Minimum" damage values were 125 percent and 75 percent, respectively, of the mean damage value.

DAMAGE CENTERS

Damages can be experienced where developed property is inundated or eroded by flood water. For the screening process, the FCWG measured damages at the following locations:

- The Columbia River below Arrow Lakes (Canada) to the U.S. Border. The reference flow is Columbia River at Birchbank, British Columbia.
- The Kootenai River from Bonners Ferry, Idaho to the Canadian Border. The reference stage is Kootenai River at Bonners Ferry, Idaho.
- The Flathead River from Columbia Falls, Montana to Flathead Lake. The reference flow is Flathead River at Columbia Falls, Montana.
- The shore of Flathead Lake. The reference lake elevation is Kerr forebay.

- The Flathead/Clark Fork River from Kerr Dam to Thompson Falls Dam. The reference flow is Kerr Dam outflow.
- The shore of Pend Oreille Lake. The reference lake elevation is the Albeni Falls Dam forebay.
- The Pend Oreille River from Albeni Falls Dam to the Canadian Border. The reference flow is Albeni Falls Dam outflow.
- The Clearwater River from Orofino, Idaho to Lewiston, Idaho. The reference flow is Spalding, Idaho.
- The Columbia River below Bonneville Dam to the mouth. The reference flow is Columbia River at The Dalles, Oregon.

The Tri-Cities area (Pasco, Kennewick, and Richland, Washington) can also experience damage, but this location was not used in the screening process. The reason is that the levees protecting the Tri-Cities area have a level of protection higher than any possible regulated flow anticipated for the years 1929 through 1978 available for the SOR study.

The shoreline damages for Flathead and Pend Oreille Lakes are significantly smaller than the damages associated with outflow from those lakes. Therefore, the shoreline damages were not allowed to vary independently (i.e., not a decision variable to Supertree), and those damages were added to the downstream damages for the appropriate project.

The damages at all the above United States locations are based on economic inventories of the effected areas performed by the Corps of Engineers District offices. The Canadian location is solely an estimate based only on known historic flow damage levels, but without economic data. As better data becomes available for the Canadian damage center, they will be incorporated into the FCWG screening model. The FCWG will work with the Economics Group to develop better estimates for the full-scale analysis phase of SOR.

VALUES MEASURES SELECTED FOR FLOOD CONTROL

For screening, the flood control value measure is dollars of damages. Damages were determined using a flow (and sometimes lake elevation) versus damage relationship; the higher a water surface stage during a flood, the larger an amount of economic damages occurs in conjunction with inundation of developed property. System flood damage is the sum of damages from each of the seven damage centers. This measure will be appropriate for years with controlled flows, but will yield no information in lower runoff years having no historic flood.

MONTH AVERAGE VERSUS PEAK FLOW

Flood control damages are calculated as the damage occurring with maximum day average or instantaneous stage or flow observed in each year. Since the hydroregulation models used by ROSE produce only month average (or half-month in April and August), the FCWG derived a relationship between month average and peak day flow. Each month of each year is generally unique, reflecting the shape of runoff hydrographs. For each month two to four items of data were available to describe the relationship:

- An observed peak and corresponding month average flow. This piece of data could be regulated, partially regulated, or unregulated depending on history.
- An unregulated peak day flow or stage is available for all years from a previous study, and month average unregulated values can be computed from daily hydrographs.
- A regulated peak day flow or stage is available from a late 1960's flood control study (designated "002") for the 1929-1968 period with monthly values computable from daily hydrographs.
- A regulated peak day flow or stage is available from a 1987 flood control study for most large runoff years and for a few medium and low years with monthly values computable from daily hydrographs.

The two to four points of data for each month were used to derive a simple linear relationship of peak versus month average flow or stage. These relationships do not account for other factors effecting a daily regulation for flood control, but they do account for general trends and were judged suitable by work group members for the SOR screening process.

DAMAGE DETERMINATION

A spreadsheet developed in Excel software was selected to perform the screening value measure calculations for the FCWG. In general, the calculation consists of entering a regulated month average flow from the hydroregulation models into the spreadsheet. The month average value is translated via a table lookup into a peak day flow. This is repeated for one or more months in each year in which a maximum annual peak could occur. The FCWG prepared a tornado diagram which showed that the hydrology (magnitude of streamflow) variable influences damages the most. The result as maximum day flow for the year is translated via table lookup into damage in dollars. Each year will have a representative damage for each alternative regulation considered. Screening alternatives were compared to the appropriate base by subtracting the system damages for the alternative from the base case system damages. Some locations require more steps to derive the damage figures. For example, the damage reference at Bonners Ferry, Idaho is stage. However, stage is related to peak flow at Bonners Ferry and the corresponding lake elevation of Kootenay Lake in British Columbia due to a backwater effect from Kootenay Lake upstream along the Kootenai River to Bonners Ferry. For the screening process this was simplified to a relationship between peak flow at Bonners Ferry and an end-of-month elevation at Kootenay lake. Also, month average flow is not available from the Hydrosim model for Bonners Ferry. Therefore, a relationship was developed between month average outflow at Libby Dam and peak day flow at Bonners Ferry. Several lookups are required in the spreadsheet to derive a damage value from Libby month average outflow and Kootenay Lake end-of-month elevation. Some similar methods are required at other locations, but in general the method of calculation is as described above.

NAVIGATION WORK GROUP SCREENING PROCESS

MODEL DESCRIPTION

Two screening models were developed for assessing navigational impacts from the various alternatives. One model calculates the impact on navigation at the four lower Snake River projects — Lower Granite, Little Goose, Lower Monumental, and Ice Harbor — while the second deals with the impact on log rafting operations above Dworshak Dam.

The value measure for both models is increased transportation costs. The influence diagrams (See Figures 3-18 and 3-19) detail the relationships between elements that effect the value measure.

FIGURE 3-18

LOWER SNAKE RIVER SCREENING MODEL INFLUENCE DIAGRAM

FIGURE 3-19

DWORSHAK SCREENING MODEL INFLUENCE DIAGRAM

In both screening models, the variables used are hydrologic conditions, quantities of transported commodities, and increased transportation costs. Sensitivity analysis showed all three to be significant in determining navigation impacts, so all three were retained for the screening process.

ASSUMPTIONS

Lower Snake River Projects Model

1. Transportation from the Snake River to Portland occurs year round. Monthly quantities of transported commodities are used for three representative years. The low, medium, and high commerce years and associated probabilities are as follows:

	Calendar Year	Probability
Low	1985	0.05
Medium	1990	0.85
High	1989	0.10

- The model assumes there is no commercial storage capability anywhere in the system. All products are shipped without delay. Between minimum operating pool (MOP) and 2 feet below, it is assumed that barges will be light-loaded, and the resultant increased cost is calculated. At greater than 2 feet below MOP, it is assumed the commodities are shipped by the next available mode of transportation, either truck or rail car, and the cost of the alternative is calculated.
- To account for possible variations in alternative transportation costs, these costs were varied through a range of + 25 percent from a baseline value. The associated probabilities of occurrence are follows:

	Probability
Low	0.05
Medium	0.70
High	0.25

- The model assumes there are sufficient numbers of rail cars or trucks to carry the additional volume of commodities and that Portland rail and truck offloading facilities are capable of handling the diverted commodities.
- Only the annual tonnage transported for grain, wood products and paper, and wood chips and logs was entered for each project for the high, average, and low commerce years. These three commodities account for over 90 percent of the downstream barge traffic. All commodities either originating in or destined for a pool or a project are treated as though they are shipped from that pool to Portland. This assumption ignores local river traffic, but a review of the 1990 data shows that no significant error is introduced by this assumption. Petroleum products are not included, as they are predominantly an upstream moving commodity, with the largest portion of traffic between Portland and the McNary pool.

Dworshak Dam Model

- The annual high and low log quantities, measured in million board-feet (mbf), were for 1987 and 1989, respectively. A medium year was calculated from the two. The following range of probabilities for each volume condition is used for the analysis.

	Volume (mbf)	Probability
Low	14	0.20
Medium	26	0.60
High	50	0.20

7. The model assumes the annual log quantities are divided equally among the four dump sites on Dworshak pool.

Dump Site Elevation (ft)	Min. Operating
Little Meadow Creek	1580
Little North Fork	1570
Benton Creek	1570
Milk Creek	1590

8. Sites are used from May to October, with the following distribution of the annual volume:

Month Annual	Percent of Volume
May	10
June	15
July	25
August	25
September	15
October	10

9. Until the pool elevation drops below 1570, logs are trucked to the nearest usable site on the pool. When the pool elevation falls below 1570 feet, logs are trucked to Lewiston, Idaho. The range of added cost for transporting logs to a different site or to Lewiston is as follows:

	Added Cost (\$/mbf/mi.)	Probability
Low	280.5	0.05
Medium	374.0	0.70
High	467.5	0.25

DISCUSSION

The following standard qualitative comments are relevant to the alternatives based on the specific impact.

Dworshak Dam Impacts

1. **Log Storage on Dworshak Pool.** Some temporary storage of logs occurs at the Dworshak log dumps, which the model does not account for. As a result, the screening model shows a cost impact associated with even the base case water condition. As this statement applies to nearly all of the alternatives screened, it will not be listed separately in the Navigation Work Group's observations in Volume 2.

All Outages or Restrictions on Lower Snake or Columbia River

2. **Lost Grain Sales.** The model assumed sufficient rail cars, trucks, and offloading capacity was available in the system to handle the increase in commodity volume moving by alternative routes, should barge navigation on the lower Snake and Columbia Rivers be curtailed. This

assumption was later found to be untrue. The result of insufficient capacity would be to lose grain sales simply because there would not be means to get the commodity to market. The model does not account for the impacts of lost sales. Members of the Navigation Group have serious concerns about the loss of sales, and, potentially, the long-term loss of the world market share of Northwest grain exports, if the cheapest transportation method, barging, is interrupted more than a few weeks annually.

3. **Transportation Infrastructure.** Representatives of the transportation agencies from the states of Washington and Oregon have expressed concern that the highway and rail systems would be physically inadequate to handle the increase in traffic volume that would occur if all the grain normally barged during an extensive river outage goes by an alternate land route. Upgrading the existing road system in rural areas would cause a reduction in the transportation funds in both states that would not be fully recovered under existing State or Federal highway revenue allocation formulas. As a result of what is essentially a Federal action, states would be forced to divert transportation funds from other areas, resulting in unmet needs in locations far removed from the Columbia River.
4. **Non-Movement of Wood Chips.** The major hauler of wood chips has indicated it is unlikely that other methods of transportation would be pursued for wood chips because the product value is too low to justify a more expensive transportation alternative. This would increase the cost of river outages.
5. **Rate Adjustments.** The model does not address rate increases that would be necessary to offset fixed expenses during navigation closures. The magnitude of the adjustment would depend on the duration of the closures.
6. **Maximum Optimal Flows Exceeded.** Two areas on the Snake River — the Ice Harbor Cut and below Lower Monumental Dam — were identified as having maximum optimum velocities, above which barge traffic would be affected. If the flow of the river exceeds 100,000 cfs at the Ice Harbor Cut or 150,000 cfs below Lower Monumental Dam (combined spillway and regulated flow), barge tows must be broken up and moved individually through the area. This process increases the safety hazard in this section and the transit time for the movement of commodities. The added transportation cost associated with the delays at high velocities is not accounted for in the navigation screening model.

Lower Columbia River Dam Outages or Restrictions

7. **Increased Transportation Costs.** As a result of an early understanding that MOP would be maintained on the lower Columbia River, the navigation models do not account for impacts due to reduced elevations on McNary, John Day, The Dalles, or Bonneville pools. Under this scenario, the impacts to navigation would be substantial — equal to an impact of outages on the Snake River plus the cost to ship products by alternate transportation from all the lower Columbia River pools. Where lower Columbia River adverse impacts are probable, but unaccounted for, asterisks have been placed in the Snake River impacts columns.
8. **Impacts to Deep-Draft Navigation.** Alternatives having extended drawdown periods (past June 15 of any year) are likely to adversely affect deep-draft navigation below Vancouver, Washington. In these circumstances the refill period for the lower Snake River reservoirs would

extend far into the low-flow period of the natural hydrograph for the Basin and could decrease draft on the lower Columbia River. Present deep-draft navigation practices maximize the draft of outbound ships, based on the actual stage of the Columbia River and the tides. Even small changes in available water depth can have significant adverse impacts.

9. **Increased Channel Dredging.** Flow augmentation scenarios that simulate a freshet in the lower Columbia River below Bonneville Dam will probably increase the formation and severity of shoaling conditions in the navigation channels. This would increase the dredging needed to keep the channel clear as compared to present practices. If high flows are immediately followed by low flows while reservoirs are refilling, the impact on shipping due to increased shoaling will be compounded by the loss of water elevation.

CULTURAL RESOURCES WORK GROUP SCREENING PROCESS

INTRODUCTION

The Cultural Resources screening model addresses the incidence of exposure occurring to known archeological and historic properties from the effects of 90 alternatives for the System Operation Review (SOR). The model does not consider the other potential impacts listed in the discussion below or assess the impact of requirements mandated under Federal cultural resources laws.

The screening model estimated the proportion of site exposure stemming from fluctuations of pool levels in John Day Reservoir on the middle reach of the Columbia River and Dworshak project on the Clearwater River, a tributary of the Snake River. These projects represent the two types of reservoirs on the Columbia River system. John Day is a run-of-river project with pool fluctuations controlled and limited to a narrow range of approximately 13 feet, while Dworshak Reservoir is a storage reservoir with a pool fluctuating through a range of 155 feet.

The Cultural Resources screening model is a simplified version of the analytical approach to be applied in full-scale analysis.

MODEL ASSUMPTIONS

The screening model predicted the incidence of site exposure by correlating pool elevation with site elevations. Arbitrarily selected 10 foot (John Day) and 50 foot (Dworshak) increments served as the basic measurement unit for determining the frequency of site incidence per a given range of pool elevation. For example, a cultural property, such as a prehistoric campsite, noted at elevation 1600 feet constitutes one site; while another cultural resource, such as a large village, recorded from elevation 1450 through 1500 feet represented five, 10-foot increments and therefore five site incidences.

The 90 alternatives consist of various pool levels (mostly within the current operating limits of the projects) proposed by different user groups which model the "best" river conditions for their particular interest. Thus, a group interested in achieving the best recreation opportunities may have proposed an alternative which maximizes "full pool," since such a pool level yields the maximum recreation opportunities. Other groups, such as irrigators, may require projects to operate at full pool so that irrigation water can be withdrawn. Pool elevations at these projects might be maintained by drafting water from upstream storage reservoirs. Thus, alternatives varied with the interests/needs of particular user groups. In addition to the interests of the various users, the amount of available water runoff was incorporated into the model by using a measure of historical rainfall and snowmelt as defined by dry, semidry, normal, semiwet, and wet years.

SCREENING RESULTS

The results of screening for cultural resource effects are presented below in Table 3-14 and briefly reviewed in the following five paragraphs. The model evaluated pool elevations for each alternative for

both John Day and Dworshak projects and produced three numerical values, an expected value and values representing the 10 and 90 percent cumulative probability distribution for each of the 90 alternatives. For the following discussion, the expected value was used as an "index of site exposure."

In general, screening of alternatives indicated consistent results for the John Day project but revealed significant variations in effects for the Dworshak project. However, those alternatives which exposed a substantial number of cultural resource sites at Dworshak project also generated increased exposure at John Day project.

None of the screening alternatives changed the operating pool levels of the John Day project, although some alternatives maintained or increased "average elevations" above what normally might be expected. These actions increased the already occurring shoreline and surface/subsurface erosion within the project but decreased the opportunities for vandalism.

Substantial cultural resource site exposure occurred within the Dworshak project for some of the alternatives. This exposure was due to the effects of alternate storage and release of waters within the project. When storage releases increased, or when the pool elevation stayed low for long periods of time, the duration of exposure and associated adverse impacts increased. On the other hand, when the Dworshak pool level was maintained at a fairly stable level, near maximum elevation, site exposure decreased and only the negative effects of inundation continued, as with a run-of-river project.

The first paragraph under Alternatives Groupings below, reviews the base case for the Bonneville Power Administration (Alternative 1) and the U.S. Corps of Engineers (Alternative 2). The second paragraph reviews Alternative 44 which produced the highest site exposure index for John Day project. The remaining paragraphs discuss the range of values produced by the alternatives for Dworshak project based on examining how these various values clustered. These groupings are not even intervals, but are based on "natural breaks" which occurred when the expected values for all alternatives were grouped by 20 increment intervals starting with the minimum value of 20 and ranging to a maximum value of 654.

TABLE 3-14
REFERENCE ALTERNATIVE
INDEX OF EXPOSURE*

Groupings	Alternative	John Day	Dworshak
1.	1	204	65
	2	204	81
2.	44	218	84
3.	89	205	20
	23	204	127
4.	25	204	205
5.	31	204	285
	18	213	654

KEY:

* Index of Exposure = Site Incidence

Alternative 1 - Bonneville Power Administration's Base Case Scenario.

Alternative 2 - U.S. Army Corps of Engineers' Base Case Scenario.

Numbers higher than the expected values for Alternatives 1 and 2 indicate an increase in site exposure. Numbers lower than the expected values for Alternatives 1 and 2 indicate a decrease in site exposure.

ALTERNATIVE GROUPINGS

1. Alternatives 1 and 2 are the base cases for SOR; Alternative 1 is the base case for the Bonneville Power Administration and Alternative 2 is the base case for the U.S. Army Corps of Engineers. Within the John Day project, these alternatives yielded a site exposure index of 204 and at Dworshak project, an index of site exposure ranging from 65 to 81. For John Day the measure indicated baseline exposure of sites in the John Day project primarily along the shore line and within the fluctuating elevations bounding pool operation. Similarly, at Dworshak, the index of exposure ranged from 65 to 81 indicating operation of the project within its optimum range with limited periods where the pool was drawn to its minimum in preparation for holding seasonal high waters.

2. The largest increase in cultural resource site exposure for the John Day project occurred for Alternative 44 with a site exposure index of 218. This increase over the base case probably reflected longer lower (average) pool levels throughout the year. For the Dworshak project, site exposure for Alternative

44 fell within the upper limit of the base case but ranged up to 118. These conditions were a consequence of using the Dworshak storage waters for small increased flows in the Snake River.

3. The third grouping for Dworshak project was represented by alternatives similar to Alternative 89 (low) with a site exposure of 20 to Alternative 23 (upper end of this grouping) with a site exposure of 127. While John Day site exposure fell within the base case, the Dworshak site index ranged from full pool with little lowering of the pool to those conditions reflecting near base case operation.

4. The fourth broad grouping indicated a substantial increase in site exposure for Dworshak project. For example, Alternative 25 had a site exposure index of 205. This alternative provided for even drafting of water from storage reservoirs to meet specific target flows for anadromous fish. Within this grouping fell all of the values reflecting site exposure in the John Day project; site exposure values clustered within this range because the John Day project is a run-of-river project operating with minimal elevation changes when compared to Dworshak project.

5. The fifth broad grouping included alternatives with substantial site exposure in the Dworshak project but which produced only minor increases in site exposure in the John Day project. This group began with Alternative 31 with an exposure index of 285 and ranged to a high in Alternative 18 with an exposure index of 654. Alternative 31 used storage water at Dworshak to enhance conditions for anadromous fish resulting in increased site exposure as the pool elevations dropped with the passage of water through the project; Alternative 18 proposed, nearly as possible, natural river conditions on the Snake and Columbia Rivers and no hydroelectric generation at the four lower Snake and Columbia River projects as these projects were operated below minimum pool.

GENERAL CONCLUSIONS

Over time, it is assumed that all cultural resources experience deterioration or adverse effects to some degree, but pool elevation changes intensify the rate of deterioration at cultural sites in direct proportion to the length of time of a drawdown. Adverse site impacts stem from an increase in access leading to illegal collecting and digging, sheetwash erosion, wind and wave action, gulleying erosion due to vehicular traffic, accelerated decomposition of organic materials once relatively stable in an anaerobic environment, soil compaction possibilities and bank undercutting and slumping, terracing, seasonal variation, wet-dry cycles, freeze-thaw cycles, and bioturbation.

Other factors which influenced the rate and degree of adverse effects to a cultural property include the rapidity of the elevation change, the frequency of elevation changes, the soil type, gradient, wave action, wet and dry cycles, public use of the areas, and the type and content of the site itself (artifacts).

A few changes in pool elevation could reduce some types of adverse effects. A raise in pool level, for example, could decrease the percent of site exposed to vandalism. A lowering, in contrast, would expose more of the cultural property to potential looting. However, the potential for wave-induced erosion in littoral and shallow zones would need further assessment. Moreover, mitigative actions to protect other resources affected by various alternatives, such as wildlife habitat enhancements, bank protection, irrigation adjustments, etc., could have adverse effects on cultural resources and would need assessment on a case-by-case basis.

To evaluate adequately increased levels of deterioration of cultural resources from changes in pool elevations will require compiling improved baseline data. These data would include such factors as site type, location, categories of artifacts present, soil type and pH, slope (geomorphology), site dimensions, depth and boundaries, potential for absolute and typological dating, existence of faunal and palynologi-

cal remains, site integrity, and the potential for inclusion in the National Register of Historic Places. The process of improving baseline data may also locate previously unrecorded sites.

Legal Requirements for Assessing the Effects of Federal Actions/Undertakings

Federal agencies must comply with the following cultural resources laws and their implementing regulations:

Section 106 of the National Historic Preservation Act of 1966 (NHPA), as amended, lists the steps which must be taken to identify, evaluate, address effects, and mitigate those historic properties which could be adversely impacted by a proposed action or undertaking by a Federal agency.

Reservoir Salvage Act as amended by the 1974 Archaeological and Historic Preservation Act mandates the preservation of archaeological and historical data (mitigation) which could be adversely affected by flooding or alteration of terrain as part of a Federal, multipurpose hydroelectric project.

American Indian Religious Freedom Act requires agencies to consider the potential effect of proposed actions on traditional, sacred, and ceremonial uses within the project area.

Executive Order 11593, Protection and Enhancement of the Cultural Environment requires agencies to inventory and nominate significant cultural properties to the National Register of Historic Places. Monitoring of the historic properties for protective and preservation purposes is also required.

Archaeological Resources Protection Act of 1979 (ARPA), as amended, requires Federal agencies to take actions to prevent the vandalism and destruction of archaeological and historic sites.

Native American Graves Protection and Repatriation Act of 1990 provides for the repatriation of funerary remains and funerary associated artifacts, as well as sacred objects and objects of cultural patrimony to the appropriate Native American Tribes or groups. Any Federal action which could result in disturbance of human remains, either through ARPA or NHPA, has to be in consultation and agreement with the Native American groups.

SECTION 3.10

WATER QUALITY WORK GROUP SCREENING PROCESS

INTRODUCTION

The water quality impacts of Columbia River system regulation alternatives were evaluated quantitatively and qualitatively. Impacts on water temperature and total dissolved gas saturation were evaluated quantitatively; impacts on other parameters were evaluated qualitatively. This section describes the evaluation procedure used, including parameters evaluated, system variables, value measures, analytical tools, model simulation procedure, uncertainties, and qualitative assessment criteria.

PARAMETERS EVALUATED

In its simplest form, the operation of a reservoir system may be characterized by the amount of water released from each reservoir. Knowing the inflow to the reservoir and the reservoir capacity, this release determines the depth of the water stored in that reservoir. For storage projects, different water depths mean different intensities of light penetration and, therefore, different water temperature conditions. Likewise, different release rates lead to different retention times which, in turn, yield different flow velocities and different durations of chemical and biological processes. For run-of-river projects, release of water over the dam spillways is the primary cause of total dissolved gas saturation at and below the projects. The higher the spilled amount, the greater the saturation level.

In addition to water temperature and total dissolved gas saturation, other parameters directly affected by a reservoir system operation include (but are not limited to) total suspended sediments, turbidity, conductivity, hardness, and total organic carbon. In many cases, toxic chemicals, coliform bacteria, and radionuclides are also affected because of their linkage to streamflows in terms of transport and concentration.

In screening the System Operation Review (SOR) alternatives, only water temperature and total dissolved gas were evaluated quantitatively. These two parameters were chosen based on the following criteria: (1) water temperature and total dissolved gas are directly affected by reservoir operations; (2) they are known, major, causes of fish mortalities; and (3) sufficient data exist to develop water temperature and total dissolved gas models.

Water temperature and total dissolved gas are considered significant factors in fish mortalities. Low water temperatures reduce predation rates, increase fish guidance efficiencies (thereby reducing turbine mortalities for juvenile fish), and improve adult fish habitat. High total dissolved gas increases incidence of gas bubble diseases which are often fatal to both juvenile and adult fish.

Other water quality parameters are also important to fish and aquatic invertebrates, human health, and the general environment. Many of them, on their own or in conjunction with a reservoir operation, may exceed or fall below existing criteria and standards. None of them, however, meets all three criteria listed above and has to be, for practical reasons, excluded from quantitative analysis at this time.

BASIC RESERVOIR SYSTEM VARIABLES

SOR alternatives formulated by the various work groups were designed to achieve specific objectives. In a sense, they represent several competing proposals for regulating the Columbia River system. Examples include keeping reservoirs full during the recreation season to maximize recreation benefit; scheduling a given range of flows and/or low pools to speed up fish outmigration, minimize pumping costs for irrigation, protect properties from flooding; etc. Work groups were free to pursue objectives as restrictive or as open-ended as they saw fit, without having to abide by existing project operating criteria or authorized project purposes.

Based on the set objectives and the physical limitations of the system, the River Operation Simulation Experts (ROSE) used computer models to calculate the flows and reservoir elevations required to accomplish these objectives. When project outflows exceeded the hydraulic capacity of the powerhouses or when there was no energy load to serve, ROSE also provided the amount of water that must be spilled past the dams.

For each alternative, ROSE made data on elevations, outflows, and spill at various reservoirs and stream locations along the Columbia River system available to all work groups for further analysis. These data covered all 12 months of the 5 years selected for the analysis, namely 1931, 1940, 1938, 1957, and 1956. These years represented a wide range of runoff conditions, including a dry, semidry, average, semiwet, and wet flow year respectively. Each year was further broken into 14 periods: Two (15-day) periods each in April and August, and one (30-day) period each for the remaining 10 months. The Water Quality Work Group used the flow, reservoir elevation, and spill data calculated by ROSE as input to its water quality models. These variables characterize the various alternatives under consideration; they changed from alternative to alternative.

VALUE MEASURES

The Water Quality Work Group concentrated on the time windows it deemed most critical to fish, namely April through September for total dissolved gas, and July through September for water temperature. For other periods of the year, only a cursory check was made to see if the projected flows were above or below known historical minimum values, and if major spill occurred for extended periods. Lower-than-minimum historical flows could indicate inadequate assimilative capacity for the stream reaches involved. Extended spill periods could mean total dissolved gas levels exceeding State standards, and harmful conditions for aquatic invertebrates and other aquatic life forms. Adverse, as well as beneficial, benefits were considered.

Water temperature was assessed based on predicted water temperature conditions inside reservoirs and along the stream reaches below those reservoirs. Value measures for water temperature included maximum, mean, and minimum water temperatures within the selected time-window. Total dissolved gas was assessed based on predicted saturation levels in stream reaches below dams where spill occurs. Value measures for total dissolved gas included mean and maximum saturation for the time-window. During the screening, other evaluation criteria such as duration, frequency, and rate of change of the value measures were not considered.

Results were summarized for the following three locations: Priest Rapids, on the mid-Columbia River; Ice Harbor, on the Snake River; and The Dalles, on the Lower Columbia River. Thanks to their location, these stations provided a good reflection of the cumulative impacts of actions taken in the river reaches upstream from them. Recognizing that maximum values of water temperature and total

dissolved gas may occur anywhere in the system beside the three sites, these system maximums were also provided. Finally, to reflect the uncertainties involved in the model prediction, the expected values for the average water temperature and total dissolved gas, and the 10 and 90 percent values of the same parameters were also made available.

Alternatives with value measures that stood out from the rest of the group were easy targets for either rejection or closer scrutiny. Many alternatives, however, were not that clean-cut. The list given below shows the range of criteria used in assessing the alternatives.

Steps	Assessment Criteria
I	Absolute maximum value measures predicted at any site in the Columbia River system
II	Absolute maximum value measures predicted at Priest Rapids, Ice Harbor, and The Dalles
III	Mean value measures predicted for each of the five flow conditions at: a. any site in the Columbia River system b. Priest Rapids, Ice Harbor, and The Dalles

The value measures listed above were numerically predicted for each alternative. The existing system regulation — the Columbia River system as it is now operated — was used as a base line or reference alternative. Value measures predicted for the new alternatives were compared with those calculated under the base case. Smaller value measures relative to the base case mean lesser of an impact than at present. Conversely, greater value measures denote more severe impact.

SCREENING MODELS

A. Water Temperature Model

For water temperature, a water temperature model titled COLTEMP was used to predict the value measures along the Columbia and Snake River mainstem, from Grand Coulee and Brownlee to below Bonneville. Water temperature conditions at sites not simulated by COLTEMP (e.g., Libby and Hungry Horse Reservoirs) were examined separately for localized impacts only. These conditions were expected to have minimal influence beyond their immediate downstream areas.

COLTEMP simulates reservoir and stream water temperature on a daily time step during the July-September period. The model is driven by a computer program developed by the U.S. Army Corps of Engineers' Hydrologic Engineering Center in Davis, California for the simulation of flood control and conservation system. The program is code-named HEC-5Q.

HEC-5Q calculates flows at various points in the Columbia River system, including reservoir and stream locations, in response to given operational schedules. The program then simulates water temperature and selected conservative and nonconservative constituents such as dissolved oxygen. Since the program is one-dimensional, it computes the vertical distribution of temperature and other constituents in the reservoirs and the changing water quality condition in the associated downstream river reaches in the direction of flow. It also selects the gate openings for reservoir selective withdrawal structures to meet user-specified water quality objectives at downstream control points.

Reservoirs are modeled as a series of one-dimensional horizontal slices layered one on top of the other (Figure 3-20). Each horizontal element is characterized by an area, thickness, and volume.

Within each segment, the water is assumed to be fully mixed. Inflows and outflows are treated as sources or sinks within each layer from the headwaters of the impoundment to the dam. Vertical advection that causes flow interchange between horizontal elements is governed by the location of inflow to, and outflow from, the reservoir. The transport of water quality constituents between elements is computed through effective diffusion, which can be induced by either, or both, wind and flow.

FIGURE 3-20

Figure WQ-1
HEC-5Q RESERVOIR REPRESENTATION

The stream system is represented as a linear network of segments or volume elements (Figure 3-21). Each element is characterized by length, width, cross section area, hydraulic radius, Manning's friction coefficient " n ," and the relationship between flow and depth. Flow rates are routed through the system using hydrologic routing.

FIGURE 3-21

Figure WQ-2
HEC-5Q STREAM REPRESENTATION

Both the reservoirs and streams are represented by an assemblage of fluid elements linked together by interelement flow and diffusion. The dynamics of temperature within each fluid element are calculated by a differential equation relating interelement mass transport and applying the fundamental principle of conservation of heat. Net rate of heat transfer between air and water relies on the concept of equilibrium temperature and coefficient of surface heat exchange.

The many elements that have an impact on water temperature are shown on the influence diagram in Figure 3-22. These include reservoir and stream physical characteristics, flows, and weather conditions. Flows and weather conditions are by far the major factors. Physical characteristics, which are not affected by the SOR, were assumed to remain unchanged.

FIGURE 3-22

Flows were shaped differently from one alternative to the next. They were specified as distinct variable quantities to the model, based on the flow values generated by each alternative in each of the 5 years (1931, 1940, 1938, 1957, and 1956) selected to cover the low to high run-off range.

Weather conditions need to be specified before the water temperature simulation can start. In any given year, any weather condition may occur, independent of the run-off conditions. For this reason, three different weather conditions were used in conjunction with each flow year — 1984, 1985 and 1990. For the Lower Snake River, these were average, below average, and above average weather conditions. For the rest of the Columbia River system, they just represent three separate weather conditions.

The following meteorological stations were used as indices of weather conditions: Boise, ID, Lewiston, ID, Spokane, WA, Portland, OR. Daily weather data include wet and dry bulb air temperature, barometric pressure, wind speed, and cloud cover. These data are directly available from monthly weather bulletins published by the National Weather Service.

Discharges from a reservoir were assumed to be released through the dam's normal gate settings. Although some Columbia River reservoirs (e.g. Dworshak and Libby) do have selective withdrawal capabilities, no attempts were made to set a temperature target for the outflows from those reservoirs. The same gate settings were consistently used in all alternatives, although the outflow itself was allowed to change as specified in the alternatives.

Sample calibration results are illustrated in Figure 3-23 with a plot of the computed and observed water temperature at selected locations in the Columbia River Basin. The sensitivity of hydrologic and meteorological input is illustrated on the tornado diagram shown in Figure 3-24. This diagram was drawn using Supertree, a decision analysis computer software developed by Strategic Decisions Group, Inc.

FIGURE 3-23

Figure WQ-4
COLTEMP/HEC-5Q SAMPLE MODEL CALIBRATION RESULTS

FIGURE 3-24

Figure WQ-5
WATER TEMPERATURE MODEL :
TORNADO DIAGRAM & CUMULATIVE PROBABILITY DISTRIBUTION

B. Total Dissolved Gas Saturation Model

Total dissolved gas is a complex phenomenon that generally occurs in the tailwater of hydropower projects, when flows are spilled and cause air and water to be mixed and carried to substantial depths in the plunge basin. As a result, air passes into solution in great amounts and produces supersaturation with respect to surface or atmospheric pressure. The many factors influencing total dissolved gas (Figure 3-25) include physical project and stream characteristics, flows, weather, and spill conditions. Unlike water temperature, weather conditions (mainly water temperature) have lesser of an impact on total dissolved gas. This leaves flows and spill conditions as the two major factors. A full-scale model developed in the early 1970s allows for total dissolved gas prediction under a wide variety of spill conditions. The model, however, is fairly complicated and requires considerable input. For the screening work, an empirical spreadsheet model was used instead to capture only the essence of the total dissolved gas process. This spreadsheet model predicts total dissolved gas formation and subsequent dissipation downstream from dams, on a reach-by-reach basis. Equations used for this prediction are empirical; they are based on actual field data collected since 1984 during April through September along the Columbia and Snake Rivers.

FIGURE 3-25

Spill, although variable, was grouped for practical purposes, in three groups: (1) less than 20 percent; (2) between 20 and 40 percent; and (3) greater than 40 percent of the flows passing the dams. Regression equations were developed for each of these levels at each of the Columbia River projects. Knowing the total dissolved gas value in the forebay of the upstream dam, the level of the spill at that dam, and using the relevant regression equation, the total dissolved gas in the forebay of the next downstream reservoir can be calculated.

The spreadsheet starts at Grand Coulee, on the mid-Columbia River, and Lower Granite, on the Snake River and proceeds on down sequentially in the flow direction. Total dissolved gas levels at those locations were assumed, based on historical conditions and runoff magnitude. Adjustments to those initial values were made, assuming that the chance for having high initial total dissolved gas increases with runoff magnitude — the higher the runoff, the higher the initial total dissolved gas saturation.

For illustration purposes, a set of regression curves are shown in Figure 3-26 for the reach between John Day and The Dalles Dams, starting from John Day Dam and ending in the forebay of The Dalles reservoir. Each point on the graph represents a total dissolved gas reading in The Dalles' forebay corresponding to a known level of spill and a known discharge rate at John Day Dam, taking into account the travel time between the John Day and The Dalles Dams at that discharge. Data points were grouped by spill level, and separate curves were developed by least-squares curve fitting, one for each of the three spill levels.

FIGURE 3-26

Figure WQ-7
SAMPLE DISSOLVED GAS SATURATION VS. SPILL RELATIONSHIP

*DISSOLVED GAS DISSIPATION BETWEEN JDA AND TDA
1982-1991*

The sensitivity of the total dissolved gas spreadsheet model to selected parameters is illustrated in the tornado diagram shown in Figure 3-27. This diagram was also developed using the Supertree computer package referred to earlier.

FIGURE 3-27

Figure WQ-8
DISSOLVED GAS
TORNADO DIAGRAM & CUMULATIVE PROBABILITY DISTRIBUTION

MODEL RUN PROCEDURE

A. COLTEMP/HEC-5Q Model

The screening option developed for HEC-5Q uses a modified main routine with temporary input data sets and repeatedly simulates temperature for any combination of flow year type and meteorology for any number of alternatives. Major program steps include:

1. read and process operation study results to develop monthly average reservoir inflow and release rates for each of the five flow year types using the mass balance procedure described below;
2. read a standard HEC-5Q input data set which provides all invariant data describing the Columbia River system;
3. read three files containing meteorological and other data specific to July, August and September 1984, 1985, and 1990;
4. generate temporary HEC-5Q input data set for each of the five flow years and three sets of meteorological data, and then simulating daily average temperature with the HEC-5Q program; and
5. process an output file to determine the monthly average, minimum, and maximum release temperature at each dam.

A mass balance procedure was used to generate the inflow and outflow records and account for evaporation, change in reservoir elevation, reservoir outflow and spill, and diversion at Grand Coulee. The mass balance begins at Bonneville and progresses upstream. Positive flow imbalances were treated as local flows. When negative flow imbalances occurred, the release from the upstream reservoir was reduced to eliminate negative local inflows. Some alternatives specify zero releases from Dworshak or Brownlee Reservoirs. These zero flows were overridden by the minimum required flow specified by the standard data set.

B. Total Dissolved Gas Spreadsheet Model

Calculation on the total dissolved gas spreadsheet was comparatively more straightforward. Monthly flow data regulated by the various alternatives were entered in the model for the period April-September in each of the five flow years. Initial total dissolved gas values were also specified at Grand Coulee and Lower Granite reservoir forebays, based on historical data and the magnitude of the runoff. Spill data were converted into the three spill levels one through three by the model and used in the appropriate dissolved gas saturation dissipation regression equations.

Total dissolved gas saturation (TDGS) values were computed in a sequential manner, from one dam to the next in the flow direction. TDGS values on the mid-Columbia River were calculated first, starting at Grand Coulee and ending at below Priest Rapids. The spreadsheet dealt with the Lower Snake River next, starting at Lower Granite and ending at below Ice Harbor. Total dissolved gas below the confluence of the Snake River was recalculated based on full mixing of the Columbia and Snake River flows. Model calculation then proceeded on to the reach below the confluence and ended at below Bonneville Dam.

UNCERTAINTIES

Once an alternative is defined, the accuracy of the water temperature and total dissolved gas alues predicted by the models for that alternative depends on the accuracy of the models and other uncertainties. For ranking purposes where relative (not absolute) values are used, it should be noted that uncertainties apply to all alternatives in the same way.

A. Model Accuracy

The COLTEMP Model is a deterministic model calibrated using 3 years of historical runoff and weather data (1984, 1985, and 1990); data on the accuracy of the simulation is available. The fact that none of the five flow years used in the regulation corresponds to the years used in the model calibration precluded a direct model accuracy determination. However, as is the case with deterministic models, prediction accuracy was assumed to remain about the same for both calibration and noncalibration years.

Data on the accuracy of the total dissolved gas spreadsheet, by way of mean and standard deviation, are also available. These data reflect the goodness of fit of the regression equations used. Based on statistical properties, model predictions have a 68 percent chance for falling in a range of one standard deviation on either side of the mean; 95 percent within two standard deviations of the mean; and 99.7 percent within three standard deviations of the mean. However, since the total dissolved gas model is empirical, its accuracy outside of its original calibration data base is unknown. This only affects model prediction for alternatives that operate under very different physical conditions that at present. Reservoir drawdown operation, under different hydraulic heads, is an example.

B. Input Uncertainties

For both models, major variables and uncertainties include:

1. hydrology - which of the five flow years will occur?
2. initial conditions - which water temperature and total dissolved gas conditions should be used to adequately reflect what happened before the model starts its calculation (i.e., July for water temperature and/or April for total dissolved gas)?
3. weather conditions - which of the three meteorological conditions will occur?

Uncertainties associated with those variables are linked with the chances for having any one of the elements listed above to also occur in any given year. The following general guidelines and considerations were used in making an estimate in each case.

1. Hydrology - In the screening studies, each of the 5 years used in the model runs is associated with a given probability of occurrence. The following probabilities calculated by ROSE based on flow duration-frequency analysis, were used:

Year	Probability
1931	0.06
1940	0.18
1938	0.50
1957	0.18
1956	0.08

2. Initial Conditions - Initial conditions for water temperature apply to deep impoundments (e.g., Grand Coulee, Dworshak, and Brownlee Reservoirs). An average water temperature profile was specified based on historical data collected for July 1. Initial conditions for total dissolved gas depend not only on conditions existing at the reservoirs but also further upstream. Probabilities for more severe initial conditions than those observed in the past to occur had to be estimated.

3. Weather Condition - It was assumed that any one of the three weather conditions can occur in conjunction with the operation of any alternative (one chance out of three).

QUALITATIVE ASSESSMENT

As mentioned earlier, effects of system regulation alternatives on many water quality parameters are non-quantifiable and, because of the uncertainties associated with quantitative estimates, strict numerical evaluation for those parameters had not been attempted. In this case, qualitative impact determination (or appraisal) of the proposed operational changes was made using professional judgment. The relative merits of each alternative were discussed in group meetings, and the perceived significance of the resulting water quality impacts were rated according to the scale shown below. The impacts are considered "negative" if degradation in existing water quality conditions are anticipated. By the same token, the term "positive" impact refers to water quality improvements.

Rating	Meaning
-2	significant negative impacts
-1	minor negative impacts
0	no impacts
1	minor positive impacts
2	significant positive impacts

The following general considerations were also used in guiding the qualitative assessment:

1. Use of storage from Dworshak and other deep impoundments for the purposes of controlling downstream stream water temperature shows some promise and deserves close review.
2. Spill ought to be used sparingly to avoid total dissolved gas saturation that exceeds State standard and creates serious problems for fish.
3. Large pool fluctuations should be minimized because of potential impacts on bank erosion, sediment resuspension, recreation, resident fish, and reservoir eutrophication.
4. Minimum instream flow requirements for fish and aquatic life or assimilative capacity must be met. Providing lower than existing historical flows at any site could violate those requirements.
5. There are other potential sources of water quality problems. Alternatives that affects irrigation return flows, effluent contaminant loadings, sewerage outfalls, groundwater movement, etc., ought to be closely examined for possible adverse impacts.

Results of the qualitative assessment using arbitrary rating indices are summarized below and illustrated in Table 3-15. For total dissolved gas (TDGS), mean system weighted values were used as criteria. For water temperature (WT), the criteria was mean weighted values at Priest Rapids (PRD), Ice Harbor (IHR), and The Dalles (TDA) (more visible and more attuned to fish requirements).

TABLE 3-15

Alternatives No./Symbol	TDGS	WT	Others	Observations
1 AMG BBPA				some spill for fish passage
2 AMG-BCOE				--ditto--
3 AMG TAR1				
4 AMG TAR2	-1			spill @IHR
5 AMG TAR3	1			minor improvement in TDGS
6 AMG FEE	-1			
7 AMG URCB				
8 AMG-URCC				
9 AMG-SRFL01	-2			spill @PRD and IHR
10 AMG-SRFL02	-1			spill @PRD.
11 AMG-SRFL03	-2			high spill @PRD/IHR
12 AMG-SRFL04	-1			
13 AMG-SRFL05	-2			high spill @IHR
14 AMG-SRFL06				
15 AMG-SRFL07				
16 AMG-SRFL08				
17 AMG-WASH		1		rel.for temps control
18 ANA-EM1		-2	-2	excessive spill/increase in WT
19 ANA-FU1		-2		spill @PRD and TDA
20 ANA-FL1		-1		increase TDGS @TDA, small WT reduction @TDA
21 ANA-FL2		-1	1	increase TDGS @TDA, small WT reduction @IHR
22 ANA-FL3			1	small increase TDGS @TDA, small WT reduction @IHR and TDA
23 ANA-4YRFDST1				some increase TDGS @TDA, very small WT reduction
24 ANA-4YRFDST2				increase TDGS @TDA, slight WT reduction
25 ANA-4YRALST1	-2			spill @PRD,TDA
26 ANA-4YRALST2				
27 AMG-CBFWAB		1		
28 AMG-CBFWAMODB	1			temps reduced @IHR
29 ANA-FISH				
30 ANA-STEP1		1		slight WT reduction @IHR
31 ANA-STEP2		2		temps red. (IHR)
32 ANA-STEP3		2		ditto
33 ANA-STEP4		2		ditto
34 ANA-STEP5	1			minor WT reduction in the system
35 AMG-GOAL				
36 AMG-NPPC1				
37 AMG-NPPC2				
38 AMG-92EIS				
39 AMG-NMFS		2		temps.red.@IHR
40 AMG-NPPCF				
41 AMG-URC50	-1			
42 ROS-XXOBS				not run
43 FLD-VARQ				
44 AMG-RRPL01				
45 AMG-RRPL02				
46 AMG-RRPL03				
47 AMG-RRPL04				

TABLE 3-15 (continued)

Alternatives No./Symbol	TDGS	WT	Others	Observations
48 AMG-RRPL05				
49 AMG-RRPL06B				
50 AMG-RRPL07B				
51 ECN-CBFWA	1	1		
52 ECN-CBFWAMOD	1	2		
53 AMG-DRAWB		1		
54 ECN-NPPC85				
55 FLD-NOSYS				
(RES-STBLPL)				
56 RES-FULPL	-1			
57 RES-WRT				
58 RES-MAX				
59 REC-OTPT		-1		
60 REC-OTPF		-1	1	
61 REC-ACC		-1		
62 IRR-OPT1		-1		
63 IRR-OPT2		-1		
64 IRR-OPT3		-1		
65 RES-IRRFLO	-2			spill @TDA,PRD
66 WLD-IDEAL	-1			
67 WLD-REAL				
68 AMG-POOL				
69 AMG-POOL2				
70 RES-SWAP	1			
71 RES-COMP				
72 RES-FLD		-1		
73 RES-FECT		-1		
74 REC-OTPT2	-1			
75 REC-OTPF2	-1	1		
76 REC-ACC2		-1		
77 PWR-CPMAX				
78 PWR-AVOP				
79 AMG-IRRFLO2	1	1		
80 AMG-CORPSBOR				not run
81 AMG-CAN				
82 AMG-RRPLSC		-1		
83 AMG-RRPL7C	1	-1		
84 AMG-DRAWC		-1		
85 ANA-FU1B		-2		spill @PRD,IHR
86 FLD-NOSYS2	-1			
87 FLD-VARQ2	-1			reduce spill @TDA
88 AMG-92EIST		2		water temp.reduction
89 RES-IRRFLO2	-2			spill @PRD,IHR
90 AMG-IRRFLO		-1		

INSIGHTS GAINED FROM SCREENING AND PROPOSED CANDIDATE SYSTEM OPERATING STRATEGIES FOR FULL-SCALE ANALYSIS

INTRODUCTION

Screening of 90 alternatives in the SOR produced a massive amount of quantitative and qualitative information. The final objective of screening is to synthesize this information and use it to propose fewer alternatives for full-scale analysis. The SOR team will analyze these alternatives, also known as system operating strategies (SOS) and document the findings in the Draft SOR Environmental Impact Statement. This chapter presents insights gained through screening by river use, presents a summary preference ranking of the 90 alternatives as determined from the work groups' results, describes the process the team, including the work groups, used to develop the candidate SOSs, and presents these candidates for broader public review.

INSIGHTS GAINED

Power

In general, nearly all of the alternatives analyzed in screening resulted in increased power system costs. There was a huge range in impacts, from a few alternatives showing reductions in power costs to alternatives increasing power costs by several billion dollars per year. The type of resource chosen to replace hydrosystem power losses significantly affected these costs, although did not substantially change the order of alternatives from least to most expensive.

The screening analysis brought into question traditional power planning methods. When hydrosystem flexibility is reduced, resource planners must closely examine the need for resources. Relying on a new resource to cover an average annual deficit will not be possible if the hydrosystem is unable to shape the energy from that resource into the months where it is needed. Consideration of the worst monthly deficit rather than average annual deficits is likely to be necessary when replacing hydrosystem losses.

Also, reduction in hydrosystem flexibility raises a number of capacity/hourly questions. Will the hydrosystem be able to deal with daily swings in energy needs? Will other resources need to be purchased to cover these swings? The screening phase pointed out the need to analyze these issues in the full-scale analysis.

Recreation

Screening analysis was confined to a representative sample of storage projects and four important recreational activities — boating, fishing, picnicking/camping, and swimming. Models were developed to quantitatively estimate recreation participation impacts, measured in visitor-hours, for four major storage projects. For run-of-river projects and free-flowing river reaches below Federal projects, impacts were qualitatively estimated based on professional knowledge and familiarity with operating characteristics and recreation facilities in these project areas. The overall

ranking of the 90 alternatives screened was based on both quantitative modeling results and qualitative impact assessments.

Twenty-seven screening alternatives generated good to very good overall recreation benefits. The majority of these included operations which maintained storage projects at or near full pool and run-of-river reservoirs at or near minimum operating pool (MOP) levels during the primary summer recreation season, without adversely impacting downstream flows. Those alternatives which achieved full pool without comprising downstream recreation opportunities included those which modified the flood control rule curves to increase early spring refill probabilities. This category of alternatives basically maintains projects within normal operating ranges so that all recreation facilities remain usable and accessible to the recreation public.

In some alternatives, full-pool elevations were achieved at the expense of extremely high or low downstream flows. These involved operating alternatives which significantly modified or adjusted existing flood control rule curves and returned the system to a more natural stream flow environment. Several irrigation and flood control alternatives that reduced flood control flexibility produced positive recreation benefits at storage reservoirs, but, in some cases, adversely affected downstream flows during the spring/early summer recreation period, particularly below Bonneville Dam. This group of alternatives demonstrated the tradeoff between reservoir and downstream recreation which must be balanced when considering multi-purpose alternatives.

Recreation opportunities at storage and run-of-river projects were most severely affected by most of the drawdown and flow augmentation alternatives considered in screening. This involved 42 alternatives. When reservoir storage was used during the spring and summer to augment anadromous fish flows, reservoir recreation participation declined dramatically as facilities became unusable at extremely low reservoir levels. Similarly, alternatives that lowered Snake River run-of-river projects to below MOP to increase water velocity and potentially anadromous fish survival rendered all recreation facilities at these run-of-river projects unusable.

The remaining 21 screening alternatives were ranked fair because recreation participation did not deviate significantly from the base cases. In these instances, reservoir pool levels did not refill to optimum levels, but elevations remained at relatively stable levels throughout the primary recreation season. Correspondingly, these alternatives maintained good downstream flows and run-of-river projects operated within normal ranges.

Resident Fish

Resident fish issues are complex and diverse. For screening, it was not possible to consolidate value measures among reservoirs and rivers because of the policy questions that would have arisen as jurisdictions and management strategies were crossed. Some alternatives in screening looked good for one reservoir or location, but showed no effect over the base case for other bodies of water.

Because of the diversity of locations, species, and issues pertaining to resident fish, coupled with the traditional emphasis on anadromous fish, information on resident fish was unavailable in many instances where needed. For full-scale analysis, this means that qualitative evaluation will often need to be employed. Similarly, little information exists which can be used to translate resident fish biological values into recreational fishery values. This difficulty is one which the Resident Fish and Recreation Work Groups will continue to wrestle with.

Lake Roosevelt's consistent lack of high value measures resulted from the difficulty in operating to maximize water retention time, a goal which is opposite to that at run-of-river projects where outmigration of anadromous juveniles is desired. This occurred because the water released from

upriver storage projects to help anadromous fish must pass through Grand Coulee thereby reducing the time water remains in this reservoir before flowing downstream. For this reason, resident fish models for full-scale analysis may consider Lake Roosevelt more as a river than as a storage project.

A petition was recently submitted to the U.S. Fish and Wildlife Service to list Kootenai River white sturgeon, a resident species, under the Endangered Species Act. Because of the ongoing anadromous fish endangered species process, considerable weight is being accorded to anadromous fish concerns in developing system operating strategies. One desired operational mode for the Kootenai River sturgeon is to provide higher flows during the spring. To the extent these flows can be achieved, it should also be possible to use them to help enhance lower river flows for juvenile salmon outmigration, thus meeting two needs at once. In fact, because river fish in general are adapted to natural river flow regimens, many resident and anadromous fish are complementary rather than contradictory.

In screening, virtually all alternatives violated flow requirements currently considered necessary for sturgeon in the Kootenai River at some time during the year. These violations occurred in most of the five water years evaluated but were especially critical in low water conditions. Flow violations with the most serious sturgeon effects occurred in the spring (April through July) where a range of minimum to maximum streamflows were necessary to stimulate successful reproduction.

Screening results showed that irrigation needs complemented those of resident fish in reservoirs, because of a common desire to hold pool levels at or near full during the growing season for fish and agriculture. Recreation alternatives were not as complementary as expected, nor were all wildlife alternatives. In fact, one alternative from each of those groups resulted in Libby outflow being cut off completely in spring, which would be extremely detrimental to resident fish.

"Biological rule curves" for resident fish will likely be a more useful tool for developing system operating strategies than would absolute specifications for pool levels and flows. A biological rule curve is a reservoir operating curve that provides benefit to resident fish by recognizing relationships between water elevation and food production requirements and other life history needs of a particular species.

Wildlife

Screening analysis was limited to a representative sample of free-flowing river reaches, storage, and run-of-river projects. Quantitative models were developed at run-of-river projects and a river reach to measure changes in wildlife populations, habitat quality indices, or habitat acreage factors. A qualitative assessment based on timing of drawdowns at the five storage projects was also performed. An overall ranking of the 90 screening alternatives was based on both quantitative and qualitative impact assessments.

Overall, none of the screening alternatives were rated as very good for wildlife. In fact, a majority of alternatives (59) or 66% are rated poor for this river use. These include the three base cases, 37 flow augmentation cases, four drawdown cases, 11 stable pool alternatives, and the four power alternatives. This can be partially attributed to adverse impacts to riparian, island, wetland and other habitats resulting from system drafts at both storage and run-of-river projects, especially drafts below normal minimum operating range, and occurrence of drafts and/or fluctuations during critical wildlife spring nesting and denning periods.

Fifteen screening alternatives provided very poor conditions for wildlife. These included six flow and nine drawdown alternatives in which high flows and deep drafts (below minimum operating pool) in the spring caused severe negative effects.

Nine screening alternatives provided fair benefits to wildlife. Seven of those proposals were stable pool alternatives such as REC-OPTF and two were flow alternatives. Generally speaking, these operations resulted in no spring drawdown at storage projects and more suitable downstream spring elevation and flow conditions for successful wildlife reproduction and rearing rates. Some gains were seen in the amount of riparian and wetland acreage primarily on the Clearwater River below Dworshak and on the lower Snake River.

Four screening alternatives provided good overall wildlife benefits. Two of those alternatives (ANA-EM1, WLD-IDEAL) would draw down system elevations and stabilize them at low levels year round. Although existing wildlife populations were dramatically affected in the near term, the work group determined that significant benefits would be gained in the long term as the increased exposure of riparian and wetland acreage recovered. The remaining two stable pool alternatives (RES-FULPL, REC-OPTP2) benefited the wildlife resource by eliminating drawdowns, passing natural streamflows, and operating the system at or near full pool elevations year round.

The screening process was a unique experience for most of the work group participants. One of the most valuable aspects was the open nature of the process and the expectation held by everyone that consensus in the modeling effort was both attainable and expected. A discovery, with implications for the forthcoming full-scale analysis, was the lack of consistent or systemwide data and modeling procedures which could be quickly used in measuring wildlife or associated habitat changes. Screening verified that wildlife, and wildlife habitat as a resource is benefited by stable pool conditions, at any level, and that enhancing flows or elevations to benefit other resources, especially in the spring, would severely effect this resource. This was especially noteworthy as that many wildlife and associated riverine habitat resources are currently protected either as potential or state and federal endangered, threatened, or sensitive species.

Irrigation

Economic impacts to irrigation, municipal and industrial uses that have been quantified in this analysis were confined to reservoirs in the lower Snake River (below Lewiston, Idaho), and the Columbia River. The impacts were based on incremental costs expected to occur as the base condition at each reservoir was altered. In the analysis, increased costs were adverse to the irrigation, municipal and industrial users, while decreased costs were beneficial. The characteristics of physical facilities as they presently exist defined the base condition. Impacts not confined to the reservoirs identified were qualitatively addressed.

Twenty-one alternatives had slight to significant adverse impacts on irrigation. The majority of these alternatives included drawdown and target flow scenarios for enhancement of anadromous fish. Fifteen of these alternatives had offsetting impacts due to increased irrigation costs at some sites and cost reductions at other sites. For example, several of the lower Snake River drawdown alternatives resulted in major costs to irrigation interests pumping from the Ice Harbor pool. At the same time, irrigation interests who pump from the John Day pool and from Franklin D. Roosevelt Lake at Grand Coulee Dam experienced decreased costs.

Four of the 21 alternatives included extensive and intensive irrigation water conservation, new storage, and water right acquisition programs within the Columbia River Basin. The impacts from implementing the irrigation water conservation, new storage, and water right acquisition programs were qualitatively addressed. Costs to implement on-farm irrigation measures, improve water distribution and conveyance facilities, construct new water storage, acquisition of storage and

instream flow rights, and lease of water supplies during drought years were not estimated for the screening analysis, but could be very costly.

Fifty-two alternatives improved conditions slightly for irrigation. This resulted from pool elevations in the lower Snake and Columbia Rivers being held higher than in the base case. The improved conditions found for about half of the 52 alternatives were due solely to reduced annual energy requirements to pump irrigation water from Franklin D. Roosevelt Lake into Banks Lake.

The remaining 17 alternatives had little or no impact on irrigation.

Anadromous Fish

General — The screening analyses focused on modeling the response of juvenile salmon that migrate entirely in-river, in contrast to those that are collected at the dams and transported to below Bonneville Dam. The work group focused on these fish because they are most affected by alternative system operations. The work group also chose to analyze the results from the 1931 water condition in addition to the overall results (i.e., the composite of five water conditions). The 1931 water condition represents a low flow year in which in-river smolt migration is most at risk.

All ninety alternatives were evaluated using both the PAM and CRISP.1 models. The purpose of the screening analysis was to compare the alternatives to one another and learn what operational elements should go forward into full-scale analysis. The models were effective in doing this. The models were not intended to be used to predict absolute survival estimates for the various alternatives, as they do not consider many important elements affecting smolt survival such as interactions between stocks and fish vitality.

Low Flow Conditions — Table 4-1 shows the expected change in in-river survival of yearling chinook from the appropriate base case. The values were determined by subtracting the base case from the absolute survival values predicted by each model. The alternatives were ranked based on Snake River yearling chinook survival. Drawdown alternatives are listed separately at the bottom because the work group did not believe the necessary information was available to evaluate them adequately within the screening analysis framework. Model differences which affect the rankings are discussed later.

It became clear that in very low flow conditions little can be done operationally to dramatically increase in-river survival in the Snake River. Several alternatives defined instream flow targets to aid fish migration such as ANA-4YRFDST, AMG-NMFS and AMG-CBFWA; however, the hydroregulation models were not able to achieve the flow targets in these alternatives in low flow water years, largely due to the limited available storage and low precipitation in the Snake River basin. Alternatives which required reservoirs to pass natural flows such as ANA-FU1B and ANA-FU1C showed a moderate benefit. Alternatives such as RES-IRRFLO and RES-IRRFLO2, which simulated an additional 1 million acre feet of water being available in the Snake River for seasonal flow augmentation also showed moderate benefits. (It is unknown where this water would come from within the basin's allocation.) The vast majority of the alternatives, however, were not considerably different from the base case. Alternatives that minimized in-river survival were those created to benefit resident fish and recreation. The results from the screening process suggested that operational alternatives alone will not appreciably decrease smolt mortality in low flow years.

Average and Above Average Water Conditions — In years of average and above average water conditions, the alternatives generally provided similar benefits to yearling chinook. Flow targets were met or exceeded on the Columbia River, and spring and summer targets were closer to being met on the Snake; however, only in extremely wet years were targets of 140 kcfs in May met on the

Snake River, as proposed in AMG-CBFWA. Table 4-2 shows the overall (composite of all five water conditions) change in survival from the base case. These were ranked according to change in yearling chinook survival of fish originating above Lower Granite.

Summer Flows — Many of the alternatives that attempted to augment flows for spring migrants did so by shifting water out of the summer period, particularly on the Snake River in low flow years. However, most of these alternatives improved summer flows on the mid and lower Columbia River. Table 4-3 shows the 1931 change in average summer flows from the base case for Lower Granite, Priest Rapids, and The Dalles.

Transportation — While screening focused on in-river migration, there is another segment of the migrant population that is removed from the system at collector dams and transported, via trucks or barges, to release sites downstream of Bonneville Dam. These transported fish avoid downstream dams and reservoirs and thus incur a lower system mortality than in-river migrants. Although the screening analysis did not focus on transported fish, preliminary results from screening indicated that transportation provided substantial benefits, particularly in low flow years. Full-scale analyses will consider the response of the entire smolt population, both transported and in-river migrants, especially as the entire life cycle is examined. In addition, the balance in survival between transported and in-river migrants may change across water years for some strategies. The response of the entire smolt population could indicate that in different water years, different operational strategies are warranted, either with or without transportation.

Drawdown — Alternatives for drawdown below minimum operating pool are being considered in the Snake River to increase river velocity, thus decreasing juvenile travel time. Several drawdown alternatives were evaluated, ranging from all projects spilling the entire river at spillway crest (ANA-EM1) to drawing down lower Snake projects only while continuing to operate the turbines (AMG-DRAWC). The two models predicted significantly different results for the drawdown alternatives. PAM equated increased survival with decreased travel time and did not take into account effects of gas saturation and other possible causes of mortality. CRiSP.1 incorporated dissolved gas mortality and assumed that predator density increased as the area within the reservoir decreased, hence CRiSP.1 predicted a much lower survival. All other assumptions such as spillway survival and turbine survival remained the same. Considerable uncertainty exists with all of the assumptions surrounding drawdown. The three Federal agencies in concert with Phase II of the Northwest Power Planning Council's Fish and Wildlife Program are preparing a thorough evaluation of drawdown including various scenarios, dam reconfigurations, and mortality factors. The most promising of these alternatives will be evaluated in the full-scale analysis of the SOR.

Differences in Model Results — The two models ranked the alternatives similarly with the exception of the drawdown alternatives. As previously discussed, the two models addressed drawdown very differently, causing PAM to rank the drawdown alternatives favorably, and CRiSP.1 to rank them near the bottom. In addition, neither model addressed the requirements for facility modifications and how that could influence other input assumptions. This will need to be evaluated in full-scale analysis along with effects on adult passage.

CRiSP.1 predicted higher absolute survival values than did PAM, particularly in low water conditions such as 1931. PAM predicted a system survival for the base case of between 5 and 6 percent for spring chinook originating above Lower Granite Dam, while CRiSP.1 predicted a system survival of about 14.5 percent. Over all five water conditions, the difference was much less, with PAM predicting a system survival of 22.4 percent and CRiSP.1 predicting about 26 percent. CRiSP.1, being a mechanistic model, was not able to reproduce the highest mortalities observed from the Sims and

Ossiander data, while still making reasonable assumptions for fish swimming behavior. Again, this highlighted the uncertainty surrounding the absolute survival values. However, this was not an important difference in screening since the purpose of screening was to compare and rank alternatives, not evaluate fish survival in absolute terms.

Another difference was that PAM was much more sensitive to changes in flow than was CRiSP.1. PAM relied on a single period average flow value to which all the fish were subjected. There was no variability associated with a daily or weekly distribution. The only variability came from the water condition, expressed as a single flow index value. When a single water year such as 1931 was focused on, the hydrologic variability in flow was eliminated. CRiSP.1 shaped the average monthly flow into daily flow values using a flow modulator. In doing so, a small change in the monthly average flow would increase the daily average flows for only a few days. At the same time, CRiSP.1 spread out the fish migrations so that not all fish were subjected to the same daily average flows.

Summary — In conclusion, the screening process was a learning experience for the work group. The strengths and limitation of the two models were discovered, and they were able to rank the alternatives comparably. Screening highlighted that a better understanding of the mechanisms involved in drawdown is needed before an adequate evaluation can be performed. Screening revealed that juvenile survival may be difficult to improve in low flow conditions by operational means alone, particularly in the Snake River, and that augmenting spring flows on the Snake River tended to impact summer flows. Full-scale analysis will have to evaluate the effects of transportation on smolt survival and also evaluate the full life-cycle of the salmon.

TABLE 4-1

1931 Change in Survival of Yearling Chinook from Base Conditions (Shaded) As Predicted by Two Passage Models: CRiSP.1 & PAM

Survival estimates for each of three river reaches in the 1931 water year are presented; Lower Granite to below Bonneville (LWG), Wells to below Bonneville (MIDC), and below McNary to below Bonneville (JDAY). B/C indicates which base case to compare to (B means AMG-BBPA, C means the AMG-BCOE).

Ranked by Lower Granite survival (change from base case) CRISP.1					Ranked by Lower Granite survival (change from base case) PAM						
		Base cases represent	LWG	MIDC	JDAY			Base cases represent	LWG	MIDC	JDAY
		absolute survival values	1931	1931	1931			absolute survival values	1931	1931	1931
#		Alt. Name	Ev	Ev	Ev	#		Alt. Name	Ev	Ev	Ev
1	B	AMG BBPA	14.4	15.8	48.5	1	B	AMG BBPA	53	33	26.5
2	C	AMG BCOE	14.8	14.9	50.1	2	C	AMG BCOE	60	47	29.7
23	B	ANA 4YRFDS1	4.8	2.5	3.9	65	B	RES IRRFLO	8.2	9.8	23.7
25	B	ANA 4YRALST1	4.7	2.5	4.2	89	B	RES IRRFLO2	8.2	9.8	23.7
65	B	RES IRRFLO	4.6	4.4	6.1	19	C	ANA FU1C	6.5	10.2	21.9
39	B	AMG NMFS	4.1	-0.3	2.0	85	B	AMG FU1B	6.2	8.7	21.5
89	B	RES IRRFLO2	3.9	4.3	5.8	39	B	AMG NMFS	5.3	0.9	8.7
26	B	ANA 4YRALST2	3.4	2.4	4.1	22	C	ANA FL3	4.8	5.1	10.1
22	C	ANA FL3	3.2	4.5	2.4	46	C	AMG RRPL3	3.9	3.6	11.5
85	B	AMG FU1B	3.1	3.8	5.7	28	C	AMG CBFWAMOD	3.9	2.9	10.6
13	C	AMG SRFLO5	2.5	-1.0	-0.5	27	C	AMG CBFWA	3.8	2.9	10.5
6	B	AMG FEE	2.4	0.8	2.5	23	B	ANA 4YRFDS1	3.8	2.8	6.6
19	C	ANA FU1C	2.3	10.8	2.9	25	B	ANA 4YRALST1	3.5	2.7	6.2
9	C	AMG SRFLO1	1.8	-0.5	0.0	13	C	AMG SRFLO5	3.3	-0.4	2.0
90	B	AMG IRRFLO	1.7	0.9	1.9	26	B	ANA 4YRALST2	2.7	2.7	6.2
28	C	AMG CBFWAMOD	1.7	0.1	0.8	31	C	ANA STEP2	2.7	1.1	5.2
79	B	AMG IRRFLO2	1.6	0.8	1.6	32	C	ANA STEP3	2.7	1.1	5.2
27	C	AMG CBFWA	1.5	0.0	0.6	33	C	ANA STEP4	2.6	1.1	5.2
72	B	RES FLD	1.3	1.4	2.5	6	B	AMG FEE	2.4	1.2	5.5
47	C	AMG RRPL4	1.3	-0.2	0.1	47	C	AMG RRPL4	2.4	0.6	3.0
31	C	ANA STEP2	1.3	-0.8	-1.3	34	C	ANA STEP5	2.3	1.1	5.2
36	B	AMG NPPC1	1.2	0.3	1.4	62	B	IRR OPT1	2.2	1.8	7.2
11	C	AMG SRFLO3	1.2	-0.8	-0.4	9	C	AMG SRFLO1	2.2	-0.2	1.4
32	C	ANA STEP3	1.2	-0.9	-1.5	72	B	RES FLD	2.1	1.9	6.8
62	B	IRR OPT1	1.1	1.0	2.3	56	B	RES FULPL	2.0	1.5	7.1
56	B	RES FULPL	1.1	1.0	2.1	17	B	AMG WASH	2.0	1.2	8.7
17	B	AMG WASH	1.1	0.0	1.1	41	C	AMG URC50	2.0	0.8	6.9
5	B	AMG TAR3	1.1	-0.1	0.9	29	C	ANA FISH	2.0	0.7	5.6
33	C	ANA STEP4	1.1	-0.9	-1.4	63	B	IRR OPT2	1.9	1.6	6.7
24	B	ANA 4YRFDS2	1.0	2.1	3.5	45	C	AMG RRPL2	1.8	1.4	4.7
37	B	AMG NPPC2	1.0	0.2	1.5	90	B	AMG IRRFLO	1.7	1.0	2.8
63	B	IRR OPT2	0.9	0.9	1.9	79	B	AMG IRRFLO2	1.7	1.0	2.8
4	B	AMG TAR2	0.7	-0.4	0.9	4	B	AMG TAR2	1.7	0.2	4.3
14	C	AMG SRFLO6	0.7	-0.5	-0.5	11	C	AMG SRFLO3	1.6	-0.6	0.2
34	C	ANA STEP5	0.7	-0.9	-1.3	24	B	ANA 4YRFDS2	1.5	2.6	6.1
40	B	AMG NPPCF	0.6	-0.2	0.3	64	B	IRR OPT3	1.5	1.1	5.2
29	C	ANA FISH	0.6	-1.0	-0.1	20	C	ANA FL1	1.5	0.8	6.1
10	C	AMG SRFLO2	0.5	-0.3	-0.3	5	B	AMG TAR3	1.4	0.4	3.7
15	C	AMG SRFLO7	0.5	-0.5	-0.9	86	C	FLD NOSYS2	1.1	1.6	4.0
64	B	IRR OPT3	0.4	0.4	1.5	36	B	AMG NPPC1	1.1	0.6	3.2
45	C	AMG RRPL2	0.4	-0.1	-0.4	37	B	AMG NPPC2	1.1	0.5	3.2
46	C	AMG RRPL3	0.3	0.0	0.1	3	B	AMG TAR1	1.0	0.5	3.9
86	C	FLD NOSYS2	0.3	-0.4	-0.5	14	C	AMG SRFLO6	1.0	-0.1	0.5
41	C	AMG URC50	0.3	-0.9	-0.3	66	B	WLD IDEAL	1.0	-0.2	5.0
35	B	AMG GOAL	0.3	-2.6	-1.7	35	B	AMG GOAL	1.0	-1.2	0.3

TABLE 4-1 (continued)

Ranked by Lower Granite survival (change from base case) CRISP.1						Ranked by Lower Granite survival (change from base case) PAM					
		Base cases represent	LWG	MIDC	JDAY			Base cases represent	LWG	MIDC	JDAY
		absolute survival values	1931	1931	1931			absolute survival values	1931	1931	1931
#		Alt. Name	Ev	Ev	Ev	#		Alt. Name	Ev	Ev	Ev
3	B	AMG TAR1	0.2	0.0	0.8	30	C	ANA STEP1	0.9	1.9	3.7
87	C	FLD VARQ2	0.0	0.5	0.7	87	C	FLD VARQ2	0.9	1.3	3.0
81	B	AMG CAN	0.0	0.0	0.4	44	C	AMG RRPL1	0.6	0.2	0.8
80	B	AMG CORPS/BOR	0.0	0.0	0.3	15	C	AMG SRFLO7	0.6	-0.2	0.1
44	C	AMG RRPL1	0.0	-0.2	-0.5	10	C	AMG SRFLO2	0.5	-0.1	0.5
43	C	FLD VARQ	-0.2	-0.4	-0.4	40	B	AMG NPPCF	0.4	0.0	0.7
12	C	AMG SRFLO4	-0.2	-0.7	-0.5	43	C	FLD VARQ	0.2	0.1	0.5
30	C	ANA STEP1	-0.3	0.8	-0.1	55	C	FLD NOSYS	0.2	0.1	0.5
78	B	PWR AVOP	-0.4	-0.3	-0.4	81	B	AMG CAN	0.1	0.0	0.3
55	C	FLD NOSYS	-0.5	0.5	0.9	68	C	AMG POOL	0.1	-1.6	-0.5
16	C	AMG SRFLO8	-0.6	-0.8	-1.2	80	B	AMG CORPS/BOR	0.0	0.0	0.2
20	C	ANA FL1	-0.7	-1.4	-1.9	12	C	AMG SRFLO4	-0.1	-0.7	-1.1
7	B	AMG URCB	-0.9	-1.6	-1.6	16	C	AMG SRFLO8	-0.2	-0.6	-1.1
38	C	AMG 92EIS	-1.0	-3.3	-4.1	42	C	ROS XXOBS	-0.3	-1.8	-0.2
21	C	ANA FL2	-1.1	-0.1	-1.9	21	C	ANA FL2	-0.5	0.2	-2.1
68	C	AMG POOL	-1.1	-2.8	-3.7	7	B	AMG URCB	-0.5	-1.1	-1.7
88	C	AMG 92EIST	-1.1	-3.2	-3.8	71	B	RES COMP	-0.7	-0.3	-4.5
66	B	WLD IDEAL	-1.2	-1.3	-1.5	8	C	AMG URCC	-0.7	-1.9	-2.9
71	B	RES COMP	-1.3	-0.3	-0.1	78	B	PWR AVOP	-1.0	-0.7	-3.9
8	C	AMG URCC	-1.7	-2.7	-4.1	38	C	AMG 92EIS	-1.2	-2.9	-5.9
67	B	WLD REAL	-1.8	-3.7	-3.7	88	C	AMG 92EIST	-1.2	-2.9	-5.9
73	B	RES PECT	-2.4	-2.2	-2.4	73	B	RES PECT	-1.3	-1.3	-6.1
70	B	RES SWAP	-2.4	-3.7	-3.7	70	B	RES SWAP	-1.4	-2.0	-7.9
58	B	RES MAX	-3.0	-6.0	-6.5	57	B	RES WRT	-1.8	-2.5	-7.3
69	C	AMG POOL2	-3.3	-6.9	-7.9	58	B	RES MAX	-1.8	-2.5	-7.3
57	B	RES WRT	-3.4	-5.8	-6.9	67	B	WLD REAL	-1.9	-1.7	-2.8
59	B	REC OPTP	-3.7	-6.4	-7.5	74	B	REC OPTP2	-2.0	-2.5	-6.7
74	B	REC OPTP2	-4.0	-6.6	-7.6	59	B	REC OPTP	-2.1	-2.5	-7.1
60	B	REC OPTF	-4.1	-6.4	-7.4	60	B	REC OPTF	-2.3	-2.5	-7.7
61	B	REC ACC	-4.1	-8.2	-9.1	75	B	REC OPTF2	-2.3	-2.5	-7.7
75	B	REC OPTF2	-4.2	-6.5	-7.7	61	B	REC ACC	-2.3	-2.7	-7.7
77	B	PWR CPMAX	-4.3	-4.8	-6.1	76	B	REC ACC2	-2.5	-2.7	-8.1
76	B	REC ACC2	-4.4	-8.1	-9.2	77	B	PWR CPMAX	-2.6	-2.1	-8.0
42	C	ROS XXOBS				69	C	AMG POOL2	-2.7	-3.9	-10.3
		DRAW-DOWNS						DRAW-DOWNS			
18	C	ANA EM1	15.3	16.1	12.7	18	C	ANA EM1	25.1	28.0	44.6

TABLE 4-2

Overall Change in Survival of Yearling Chinook from Base Conditions (Shaded) As Predicted by Two Passage Models: CRISP.1 & PAM

Survival estimates for each of three river reaches over all five water conditions are presented; Lower Granite to below Bonneville (LWG), Wells to below Bonneville (MIDC), and below McNary to below Bonneville (JDAY). B/C indicates which base case to compare to (B means AMG-BBPA, C means the AMG-BCOE).

Ranked by Lower Granite survival (change from base)						Ranked by Lower Granite survival (change from base)					
CRISP.1						PAM					
		Base cases represent	LWG	MIDC	JDAY			Base cases represent	LWG	MIDC	JDAY
		absolute survival values	Overall	Overall	Overall			absolute survival values	Overall	Overall	Overall
		Alt Name	Ev	Ev	Ev	#		Alt Name	Ev	Ev	Ev
1	B	AMG BBPA	26.7	23.0	58.7	1	B	AMG BBPA	22.4	14.3	59.3
2	C	AMG BCOE	26.1	20.7	57.6	2	C	AMG BCOE	22.4	14.4	58.1
89	B	RES IRRFLO2	2.9	2.9	2.0	65	B	RES IRRFLO	7.7	8.7	11.0
19	C	ANA FU1C	2.8	5.0	3.1	89	B	RES IRRFLO2	7.7	8.7	11.0
22	C	ANA FL3	2.5	3.2	1.0	19	C	ANA FU1C	7.0	9.8	11.4
65	B	RES IRRFLO	2.3	3.0	2.1	85	B	AMG FU1B	6.7	8.3	10.4
23	B	ANA 4YRFDS1	2.1	0.7	0.6	25	B	ANA 4YRALST1	3.9	1.1	3.2
13	C	AMG SRFLO5	1.8	0.3	0.6	56	B	RES FULPL	3.9	2.7	4.8
25	B	ANA 4YRALST1	1.7	-0.6	-0.1	13	C	AMG SRFLO5	3.6	1.0	2.1
26	B	ANA 4YRALST2	1.7	0.5	0.8	62	B	IRR OPT1	3.4	2.4	4.4
41	C	AMG URC50	1.6	2.2	1.7	41	C	AMG URC50	3.2	3.3	5.4
27	C	AMG CBFWA	1.5	0.9	1.0	63	B	IRR OPT2	3.2	2.3	4.2
55	B	RES FULPL	1.5	1.0	0.9	72	B	RES FLD	3.2	3.0	4.2
72	B	RES FLD	1.5	2.0	1.7	23	B	ANA 4YRFDS1	3.1	1.6	2.4
28	C	AMG CBFWAMOD	1.2	0.9	1.0	66	B	WLD IDEAL	3.1	2.8	5.0
62	B	IRR OPT1	1.2	0.6	1.2	64	B	IRR OPT3	2.9	2.0	3.7
21	C	ANA FL2	1.1	3.4	1.0	22	C	ANA FL3	2.8	2.6	3.3
63	B	IRR OPT2	0.9	0.7	0.5	27	C	AMG CBFWA	2.6	2.1	3.6
64	B	IRR OPT3	0.9	0.3	0.2	46	C	AMG RRPL3	2.3	1.8	3.7
87	C	FLD VARQ2	0.9	0.8	0.6	11	C	AMG SRFLO3	2.2	0.7	1.1
90	B	AMG IRRFLO	0.9	0.2	0.6	28	C	AMG CBFWAMOD	2.2	2.1	3.4
79	B	AMG IRRFLO2	0.9	0.3	0.0	9	C	AMG SRFLO1	2.1	0.7	-8.9
11	C	AMG SRFLO3	0.8	-0.2	-0.2	34	C	ANA STEP5	2.1	1.4	2.1
34	C	ANA STEP5	0.8	0.5	0.2	33	C	ANA STEP4	1.8	1.3	2.0
24	B	ANA 4YRFDS2	0.6	0.5	0.6	47	C	AMG RRPL4	1.8	0.6	0.4
33	C	ANA STEP4	0.6	0.4	-0.1	29	C	ANA FISH	1.7	1.5	2.5
86	C	FLD NOSYS2	0.6	0.1	0.0	26	B	ANA 4YRALST2	1.6	0.6	1.0
29	C	ANA FISH	0.5	0.4	0.6	86	C	FLD NOSYS2	1.5	1.2	2.0
66	B	WLD IDEAL	0.5	1.2	0.9	45	C	AMG RRPL2	1.4	1.0	1.8
10	C	AMG SRFLO2	0.4	-0.2	-0.2	73	B	RES PECT	1.4	1.7	2.4
7	B	AMG URCB	0.3	1.1	0.6	87	C	FLD VARQ2	1.2	0.8	1.4
12	C	AMG SRFLO4	0.3	-0.1	-0.2	32	C	ANA STEP3	1.1	1.3	1.8
16	C	AMG SRFLO8	0.3	0.1	0.1	60	B	REC OPTF	1.1	0.3	1.5
4	B	AMG TAR2	0.2	-0.7	-0.3	90	B	AMG IRRFLO	1.1	0.4	1.3
14	C	AMG SRFLO6	0.2	0.0	0.1	79	B	AMG IRRFLO2	1.1	0.5	1.3
47	C	AMG RRPL4	0.2	-0.2	0.5	12	C	AMG SRFLO4	1.0	0.5	0.6
44	C	AMG RRPL1	0.1	-0.6	0.1	59	B	REC OPTP	1.0	-0.8	-0.2
88	C	AMG 92EIST	0.1	-0.1	0.0	74	B	REC OPTP2	1.0	-0.7	0.1
15	C	AMG SRFLO7	0.0	0.1	-0.1	75	B	REC OPTF2	1.0	0.5	1.3
67	B	WLD REAL	0.0	-0.8	-0.8	10	C	AMG SRFLO2	0.9	0.6	0.7
68	C	AMG POOL	0.0	0.0	-0.7	4	B	AMG TAR2	0.8	-0.6	0.2
71	B	RES COMP	-0.1	-0.2	-0.2	6	B	AMG FEE	0.8	-0.6	1.4
73	B	RES PECT	-0.1	0.8	0.7	14	C	AMG SRFLO6	0.7	0.4	0.3
78	B	PWR AVOP	-0.1	0.2	0.2	44	C	AMG RRPL1	0.7	0.4	0.3

TABLE 4-2 (continued)

Ranked by Lower Granite survival (change from base)						Ranked by Lower Granite survival (change from base)					
CRISP.1						PAM					
		Base cases represent	LWG	MIDC	JDAY			Base cases represent	LWG	MIDC	JDAY
		absolute survival values	Overall	Overall	Overall			absolute survival values	Overall	Overall	Overall
		Alt. Name	Ev	Ev	Ev	#		Alt. Name	Ev	Ev	Ev
38	C	AMG 92EIS	-0.1	-0.2	-0.2	16	C	AMG SRFLO8	0.6	0.4	0.2
43	C	FLD VARQ	-0.1	0.1	0.1	21	C	ANA FL2	0.6	1.8	0.7
46	C	AMG RRPL3	-0.1	-0.7	0.2	39	B	AMG NMFS	0.6	-0.3	1.0
55	C	FLD NOSYS	-0.1	0.8	1.0	71	B	RES COMP	0.6	0.1	0.7
40	B	AMG NPPCF	-0.2	-0.1	-0.1	76	B	REC ACC2	0.6	-1.0	-0.4
20	C	ANA FL1	-0.2	0.8	-0.1	61	B	REC ACC	0.5	-1.0	-0.5
32	C	ANA STEP3	-0.2	0.3	-0.3	69	C	AMG POOL2	0.5	-1.1	-0.8
45	C	AMG RRPL2	-0.2	-0.5	0.1	20	C	ANA FL1	0.4	1.1	2.2
3	B	AMG TAR1	-0.3	-0.7	-0.7	31	C	ANA STEP2	0.4	1.1	1.5
6	B	AMG FEE	-0.3	-0.4	-0.6	40	B	AMG NPPCF	0.3	0.0	0.6
37	B	AMG NPPC2	-0.3	-0.1	0.0	43	C	FLD VARQ	0.3	0.5	0.4
69	C	AMG POOL2	-0.3	-1.8	-1.2	55	C	FLD NOSYS	0.3	0.5	0.4
80	B	AMG CORPS/BOR	-0.3	-0.1	-0.3	15	C	AMG SRFLO7	0.2	0.3	0.1
17	B	AMG WASH	-0.4	-0.3	-0.1	37	B	AMG NPPC2	0.2	0.0	0.6
39	B	AMG NMFS	-0.4	-0.9	-0.6	57	B	RES WRT	0.2	-0.9	0.0
81	B	AMG CAN	-0.4	-0.1	-0.1	5	B	AMG TAR3	0.1	-0.5	0.1
5	B	AMG TAR3	-0.5	-0.6	-0.7	30	C	ANA STEP1	0.1	0.9	1.1
8	C	AMG URCC	-0.5	0.5	-0.5	36	B	AMG NPPC1	0.1	-0.2	0.5
36	B	AMG NPPC1	-0.5	-0.2	-0.2	38	C	AMG 92EIS	0.1	0.2	-0.1
59	B	REC OPTP	-0.5	-1.6	-1.7	58	B	RES MAX	0.1	-0.9	0.0
31	C	ANA STEP2	-0.7	0.3	-0.6	68	C	AMG POOL	0.1	0.2	0.4
30	C	ANA STEP1	-0.8	0.1	-0.5	78	B	PWR AVOP	0.1	0.2	0.3
35	B	AMG GOAL	-0.9	-1.4	-1.2	80	B	AMG CORPS/BOR	0.1	0.1	0.4
74	B	REC OPTP2	-0.9	-1.7	-1.5	88	C	AMG 92EIS1	0.1	0.2	-0.1
75	B	REC OPTF2	-0.9	-0.6	-0.6	3	B	AMG TAR1	0.0	-0.5	0.2
60	B	REC OPTF	-1.0	-0.9	-1.1	17	B	AMG WASH	0.0	0.0	0.9
58	B	RES MAX	-1.1	-1.9	-1.8	81	B	AMG CAN	0.0	0.0	0.3
76	B	REC ACC2	-1.1	-2.0	-1.7	8	C	AMG URCC	-0.1	0.5	0.3
9	C	AMG SRFLO1	-1.2	0.5	0.7	7	B	AMG URCCB	-0.2	0.4	0.1
57	B	RES WRT	-1.3	-2.1	-1.8	24	B	ANA 4YRFDST2	-0.2	0.3	0.5
61	B	REC ACC	-1.4	-2.0	-1.7	35	B	AMG GOAL	-0.2	-0.9	-0.1
70	B	RES SWAP	-1.8	-3.0	-2.3	70	B	RES SWAP	-0.2	-2.8	-0.6
77	B	PWR CPMAX	-1.9	-1.7	-6.8	77	B	PWR CPMAX	-0.8	-0.7	-1.6
85	B	AMG FU1B	-7.1	2.8	-0.8	67	B	WLD REAL	-2.4	0.2	0.4
42	C	ROS XXOBS				42	C	ROS XXOBS	-6.6	-6.1	-7.6
		DRAW-DOWNS						DRAW-DOWNS			
18	C	ANA EM1	2.7	11.3	2.3	18	C	ANA EM1	18.3	31.2	24.6
51	C	ECN CBFWA	1.7	1.0	1.2	49	C	AMG RRPL6B	14.2	0.7	0.7
52	C	ECN CBFWAMOD	1.3	0.9	1.1	50	C	AMG RRPL7B	14.2	0.7	0.7
54	B	ECN NPPC85	0.5	2.2	1.2	53	C	AMG DRAWB	13.7	0.5	0.1
82	C	AMG RRLP6C	-6.5	-0.4	0.3	82	C	AMG RRLP6C	5.2	0.5	0.5
83	C	AMG RRPL7C	-6.5	-0.5	0.2	83	C	AMG RRPL7C	5.1	0.5	0.4
84	C	AMG DRAWC	-6.5	-0.4	0.3	84	C	AMG DRAWC	4.7	0.3	-0.2
48	C	AMG RRPL5	-7.5	-0.2	0.5	51	C	ECN CBFWA	4.0	2.1	3.6
49	C	AMG RRPL6B	-7.5	-0.4	0.5	52	C	ECN CBFWAMOD	2.4	2.1	3.4
53	C	AMG DRAWB	-7.5	-0.3	0.4	48	C	AMG RRPL5	2.2	0.5	0.4
50	C	AMG RRPL7B	-7.6	-0.4	0.4	54	B	ECN NPPC85	0.5	-0.1	0.8

TABLE 4-3

1931 Change in Period Average Flow from Base Conditions (Shaded)

Flow changes for each of three river reaches in the 1931 water year are presented; Lower Granite to below Bonneville (LWG), Wells to below Bonneville (MIDC), and below McNary to below Bonneville (JDAY). B/C indicates which base case to compare to (B means AMG-BBPA and C means AMG-BCOE). June2/Aug1 indicates period of mid-June to mid-August.

			Summer Migrants change in flow - 1931		
			LWG	PRD	TDA
		Base Case represents flow in Kcfs	June/July	June/July	Jun2/Aug 1
#		Alt. Name	kcfs	kcfs	kcfs
1	B	AMG BBPA	27.6	83.8	105.0
2	C	AMG BCOE	27.8	78.0	104.3
89	B	RES IRRFLO2	39.0	100.0	64.0
79	B	AMG IRRFLO2	6.8	2.1	6.8
12	C	AMG SRFLO4	6.4	-4.5	0.1
42	C	ROS XXOBS	5.7	46.9	34.7
30	C	ANA STEP1	4.5	44.4	35.3
16	C	AMG SRFLO8	4.1	-2.6	0.2
90	B	AMG IRRFLO	4.1	2.1	2.6
35	B	AMG GOAL	2.5	17.8	9.5
10	C	AMG SRFLO2	2.0	-0.3	0.1
65	B	RES IRRFLO	1.3	100.0	59.8
60	B	REC OPTF	1.0	29.6	35.4
75	B	REC OPTF2	1.0	29.6	350.4
88	C	AMG 92EIST	0.9	-7.9	2.4
15	C	AMG SRFLO7	0.8	-0.2	-0.2
11	C	AMG SRFLO3	0.5	-1.0	-1.6
24	B	ANA 4YRFDST2	0.3	38.5	27.7
44	C	AMG RRPL1	0.1	0.6	-0.3
80	B	AMG CORPS/BOR	0.0	2.0	2.0
81	B	AMG CAN	0.0	3.0	2.9
43	C	FLD VARQ	-0.1	0.3	-0.1
55	C	FLD NOSYS	-0.1	0.3	-0.1
57	B	RES WRT	-0.2	24.0	10.8
58	B	RES MAX	-0.2	24.0	10.8
38	C	AMG 92EIS	-0.3	-8.0	0.8
45	C	AMG RRPL2	-0.3	2.7	1.5
17	B	AMG WASH	-0.5	38.7	15.4
62	B	IRR OPT1	-1.1	31.6	12.3
3	B	AMG TAR1	-1.2	18.9	6.7
46	C	AMG RRPL3	-1.2	5.2	3.8
66	B	WLD IDEAL	-1.3	42.8	17.3
7	B	AMG URCB	-1.4	11.9	0.7
23	B	ANA 4YRFDST1	-1.4	38.5	30.3
78	B	PWR AVOP	-1.4	-21.6	-12.1
8	C	AMG URCC	-1.5	22.7	9.4
22	C	ANA FL3	-1.5	33.8	13.5
31	C	ANA STEP2	-1.5	31.5	17.8

TABLE 4-3 (continued)

			Summer Migrants change in flow - 1931		
			LWG	PRD	TDA
		Base Case represents flow in Kcfs	June/July	June/July	Jun2/Aug 1
#		Alt. Name	kcfs	kcfs	kcfs
32	C	ANA STEP3	-1.5	31.5	17.8
33	C	ANA STEP4	-1.5	31.5	17.8
34	C	ANA STEP5	-1.5	32.7	19.0
68	C	AMG POOL	-1.5	29.0	11.6
72	B	RES FLD	-1.5	19.1	1.7
77	B	PWR CPMAX	-1.5	1.3	-0.6
61	B	REC ACC	-1.7	25.1	18.9
70	B	RES SWAP	-1.7	1.0	-2.0
63	B	IRR OPT2	-1.9	30.6	10.4
6	B	AMG FEE	-2.1	12.1	-0.4
39	B	AMG NMFS	-2.1	52.0	29.9
5	B	AMG TAR3	-2.2	18.9	6.3
27	C	AMG CBFWA	-2.3	46.6	33.9
28	C	AMG CBFWAMOD	-2.3	46.8	33.8
69	C	AMG POOL2	-2.3	23.8	11.3
29	C	ANA FISH	-2.5	52.3	43.3
37	B	AMG NPPC2	-2.5	18.6	5.3
40	B	AMG NPPCF	-2.5	-2.8	1.7
36	B	AMG NPPC1	-2.6	18.6	5.3
64	B	IRR OPT3	-2.6	26.6	4.9
76	B	REC ACC2	-2.7	26.1	18.9
85	B	AMG FU1B	-2.8	97.8	57.2
25	B	ANA 4YRALST1	-2.9	38.5	28.1
26	B	ANA 4YRALST2	-2.9	38.5	28.1
56	B	RES FULPL	-2.9	35.0	10.7
74	B	REC OPTP2	-2.9	26.5	8.5
19	C	ANA FU1C	-3.0	115.5	68.6
20	C	ANA FL1	-3.0	55.5	32.4
21	C	ANA FL2	-3.0	-0.1	-4.2
41	C	AMG URC50	-3.0	71.9	42.7
86	C	FLD NOSYS2	-3.0	10.8	1.8
87	C	FLD VARQ2	-3.0	3.1	-3.2
14	C	AMG SRFLO6	-3.1	2.5	-0.5
47	C	AMG RRPL4	-3.8	13.8	4.6
9	C	AMG SRFLO1	-3.9	4.5	-0.6
67	B	WLD REAL	-4.2	15.5	-2.7
73	B	RES PECT	-4.3	-15.5	-0.3
71	B	RES COMP	-4.5	-3.1	-8.5
13	C	AMG SRFLO5	-5.1	3.6	-2.2
59	B	REC OPTP	-5.7	27.0	6.8
4	B	AMG TAR2	-5.9	25.1	7.2
		DRAW-DOWNS			
82	C	AMG RRPL6C	1.7	0.4	0.7

TABLE 4-3 (continued)

			Summer Migrants change in flow - 1931		
			LWG	PRD	TDA
Base Case represents flow in Kcfs			June/July	June/July	Jun2/Aug 1
#		Alt. Name	kcms	kcms	kcms
83	C	AMG RRPL7C	1.6	0.4	0.6
49	C	AMG RRPL6B	1.5	2.3	1.3
50	C	AMG RRPL7B	1.4	2.7	1.5
52	C	ECN CBFWAMOD	-0.4	41.4	38.4
84	C	AMG DRAWC	-0.4	0.9	-2.8
53	C	AMG DRAWB	-0.8	2.5	-3.5
51	C	ECN CBFWA	-1.4	46.9	34.7
18	C	ANA EM1	-2.9	126.1	84.9
48	C	AMG RRPL5	-3.8	15.2	4.8
54	B	ECN NPPC85	-5.3	18.6	2.2

Flood Control

Results from screening showed that most of the alternatives increased flood damages over the base cases. A few alternatives showed small decreases in flood damages. The worst alternatives for flood control increased damages by several hundred million dollars per year. Most of these alternatives maintained full or nearly full Canadian projects, causing large increases in flood damages at U.S. damage sites.

A number of alternatives modified flood control rule curves in order to provide more water for other uses. In some cases, increases in damages from these changes were not severe. The screening analysis demonstrated that flood control has a good deal of flexibility, which potentially could improve or enhance system operation for other uses. This will be examined in full-scale analysis.

Navigation

Because navigation impacts were directly related to water elevation at the dams, the results of the Navigation Work Group screening process were predictable. Alternatives that relied on drafting Dworshak to meet water requirements affected the log rafting operations above the dam. Draw-down alternatives affected river navigation on the Snake and lower Columbia Rivers. Alternatives requiring the permanent lowering of pools below MOP had the most severe impacts.

Several other potential impacts were identified, but not quantified. First is the possibility of impacts on deep draft navigation in the lower Columbia River during the refill period following extended drawdown operations. Second is the potential for increased shoal formation on the lower Columbia River as a result of flow augmentation or natural hydrograph alternatives. Third is the far reaching impact to the transportation planning and funding for both Washington and Oregon of extended drawdown scenarios. These three impacts are more fully described in Chapter 3.

Cultural Resources

Adverse impacts to cultural resources will increase in direct proportion to the frequency and magnitude of pool fluctuations and to the percent of sites exposed or in shallow zones. A lowering of pool elevations will expose more of the cultural property to potential looting. A raise in pool elevations will decrease the percent of the site exposed to vandalism.

The results of alternative screening are fairly consistent for the John Day Project but vary significantly for the Dworshak Project. However, as a general observation, those alternatives which have a substantial incidence of exposure on the cultural resources of Dworshak Project also increase exposure to the cultural resources of the John Day Project.

None of the proposed alternatives changed the operating pool levels of the John Day Project, although some alternatives maintained or increased "average elevations" above what might be normally expected. These "average" increases generally corresponded to alternatives that substantially increased site exposure in the Dworshak Project. For these alternatives, the actions in the John Day Project increased the already occurring shoreline and surface/subsurface erosion within the project and the opportunities for vandalism.

Substantial cultural resource site exposure occurred within the Dworshak Project for some of the alternatives. This was due to the effects of alternating storage and release of water within the project. When the frequency of storage and releases increased, or when the pool stayed low for a long period of time, the duration of exposure increased. On the other hand, when the Dworshak reservoir level was maintained near its maximum elevation, site exposure decreased and the general negative effects of inundation continued, as with a run-of-river project.

Water Quality

The alternatives were screened for water temperature and total dissolved gas saturation impacts only. Coliform bacteria, metals, chemicals, dissolved oxygen, sediment, odor, color, taste, etc., were not evaluated. As a result, direct water quality impacts on water user fields such as water supply, industrial water use, irrigation, fish, recreation, navigation, flood control, etc., were not addressed.

Alternatives were generally characterized by release amounts and end-of-period reservoir elevations. Therefore, only those water quality problems that are solvable by flow and reservoir pool manipulations were directly affected. Using monthly time steps, daily and hourly fluctuations of parameters that were important to certain aspects of water quality could not be determined. Minimum and maximum instantaneous flows, daily and hourly flow variations (rates of changes) were not defined. Therefore, pollutant concentrations, extent of bank erosion, etc., were not known. However, no alternatives were found that were fundamentally and irreparably bad or good to water quality because, in many instances, impairments to water quality can be remedied by other means than flow and reservoir manipulations.

Changes in water temperatures brought about by the various alternatives were relatively small, less than 2 degrees F. Only a few screening alternatives had reduction of high water temperature as a stated objective.

Water temperature control potential is limited in the Columbia River Basin. The number of reservoirs that are deep enough to provide adequate storage for that purpose in stream reaches used by anadromous fish is limited. Grand Coulee, Hungry Horse, and Brownlee reservoirs have no selective withdrawal capabilities. Of the two reservoirs equipped with selective withdrawal facilities, Libby is too far from the fish migration routes, and Dworshak has too limited a storage in relation to the lower Snake River flows to be fully efficient.

Total dissolved gas saturation was directly related to the amount of spill and can be alleviated by installation of spillway flip-lips which were not evaluated in screening. High spill can occur through or for the following reasons: (1) deliberate schemes to divert water away from the powerhouses to improve juvenile fish passage, (2) inadequate storage, when reservoirs are full and flood waters must be spilled, and (3) loss of powerhouse operation.

Total dissolved gas saturation in the river reaches covered by the SOR is highly dependent upon the saturation level of the flows coming from upper reaches of the basin, Canada and the Upper Snake River. Ignoring the contribution from these sources can lead to misleading results.

Alternatives that looked good for water temperature were not necessarily good for dissolved gas saturation, and vice-versa. Ranking of alternatives was made on a case-by-case basis, looking at each of the two criteria separately. By the same token, a ranking based on the summation of water temperature and dissolved gas saturation impacts would be highly skewed toward dissolved gas, because impacts on dissolved gas saturation were generally more pronounced than those on water temperature.

Model predictions on alternatives involving reservoir drawdown need to be treated with caution. Models used in the screening were not calibrated with data that reflect such a drastic operation.

PREFERENCE RANKING

Each work group completed independently a relative ranking of the 90 alternatives as shown on the following table (Table 4-4). The ranking ranges from 1 which represents the best operation for the particular use to 5 which represents the worst. The base case alternatives were ranked in the same manner as the other alternatives (e.g., AMG-BBPA represents a relatively poor operation for wildlife, but is highly ranked for power). There was not a standard distribution of rankings given to the work groups.

TABLE 4-4

Preference Ranking of Screening Alternatives

ALTERNATIVE	W O R K G R O U P											
	PWR	REC	RES	WLD	IRR	ANA		FLD	NAV	CR	WQ	
							Spring	Fall				
Base Case Alternatives												
1	AMG-BBPA	1	3	3	4	2	4	4	3	2	2	3
2	AMG-BCOE	1	3	3	4	2	4	4	3	2	3	3
42	ROS-XXOBS	1	4	3	4	2	4	2	1	2	2	3
Flow Alternatives												
3	AMG-TAR1	2	3	3	4	3	4	4	2	2	2	3
4	AMG-TAR2	2	4	3	4	3	4	5	3	2	2	4
5	AMG-TAR3	2	2	2	4	3	4	4	2	2	2	2
6	AMG-FEE	2	2	2	4	3	3	4	3	2	3	4
7	AMG-URCB	3	1	3	4	3	5	4	3	2	3	3
8	AMG-URCC	3	1	2	4	3	5	4	3	2	2	3
9	AMG-SRFL1	2	4	3	4	3	3	4	3	3	4	5
10	AMG-SRFL2	2	4	3	4	3	4	3	3	3	3	4
11	AMG-SRFL3	2	4	3	4	3	4	4	3	3	3	5
12	AMG-SRFL4	2	4	3	4	3	4	2	3	3	2	4
13	AMG-SRFL5	2	4	3	4	3	3	5	4	3	5	5
14	AMG-SRFL6	2	4	3	4	3	4	5	3	2	3	3
15	AMG-SRFL7	2	3	3	4	3	4	4	3	2	3	3
16	AMG-SRFL8	2	4	3	4	3	4	2	3	2	2	3
17	AMG-WASH	2	4	3	5	3	4	4	2	2	2	2
19	ANA-FU1C	5	2	1	2	2	2	3	5	2	1	5
20	ANA-FL1	5	1	2	4	2	5	3	3	2	2	4
21	ANA-FL2	3	1	3	4	2	5	4	3	2	2	4
22	ANA-FL3	5	5	4	5	3	2	3	3	3	5	3
23	ANA-4YRFDST1	4	4	3	4	3	2	3	4	3	4	3
24	ANA-4YRFDST2	4	4	3	4	3	3	4	3	3	5	3
25	ANA-4YRALST1	4	2	3	4	3	2	3	5	3	5	5
26	ANA-4YRALST2	4	3	3	4	3	3	3	3	3	5	4
27	AMG-CBFWA	4	5	4	5	2	3	3	3	3	5	2
28	AMG-CBFWAMOD	4	5	4	5	2	3	3	3	3	5	2
29	ANA-FISH	4	5	4	4	3	4	3	3	2	2	3
30	ANA-STEP1	4	5	4	4	2	4	2	3	3	5	2
31	ANA-STEP2	4	5	4	4	2	4	3	3	3	5	2
32	ANA-STEP3	4	5	4	4	2	4	3	3	3	5	2
33	ANA-STEP4	4	5	4	4	2	4	3	3	3	5	2
34	ANA-STEP5	4	5	4	4	2	4	3	3	3	5	2
35	AMG-GOAL	3	4	3	5	5	4	3	5	2	3	3
36	AMG-NPPC1	2	4	3	4	3	4	4	3	2	3	3
37	AMG-NPPC2	2	4	3	4	3	4	4	3	2	3	3
38	AMG-92EIS	3	2	3	4	2	5	4	3	2	2	3
39	AMG-NMFS	3	5	4	5	4	2	3	2	3	5	2
40	AMG-NPPCF	2	4	3	4	3	4	4	2	2	3	3
41	AMG-URC50	5	2	2	4	2	4	3	4	2	1	4
43	FLD-VARQ	2	2	3	4	2	4	4	3	2	3	3
55	FLD-NOSYS	1	2	3	4	1	4	4	3	2	3	3
85	ANA-FU1B	5	2	1	3	3	2	3	5	1	1	5
86	FLD-NOSYS2	3	3	2	4	2	4	5	3	2	2	4
87	FLD-VARQ2	3	3	2	4	2	4	5	3	2	2	4

	ALTERNATIVE	PWR	REC	RES	WLD	IRR	ANA		FLD	NAV	CR	WQ
							Spring	Fall				
88	AMG-92EIST	3	3	3	4	2	5	4	3	2	3	2
90	AMG-IRRFLO	1	3	3	4	3	3	2	3	2	3	4
79	AMG-IRRFLO2	1	3	3	4	3	3	2	3	2	3	2

Drawdown Alternatives												
18	ANA-EM1	5	5	5	2	5	1	3	5	5	5	5
44	AMG-RRPL1	2	5	3	4	3	4	4	3	2	4	3
45	AMG-RRPL2	3	5	3	4	5	4	4	3	2	4	3
46	AMG-RRPL3	3	5	3	5	5	4	4	3	2	4	3
47	AMG-RRPL4	3	5	3	4	3	4	5	3	5	4	3
48	AMG-RRPL5	3	5	3	4	3	?	?	3	5	4	3
49	AMG-RRPL6B	3	3	3	5	4	?	?	3	5	4	4
50	AMG-RRPL7B	3	3	3	5	4	?	?	3	5	4	4
51	ECN-CBFWA	5	5	4	5	4	?	?	3	5	5	2
52	ECN-CBFWAMOD	5	5	4	5	4	?	?	3	5	1	2
53	AMG-DRAWB	2	3	3	5	4	?	?	3	5	4	4
54	ECN-NPPC85	2	3	3	5	3	?	?	3	5	3	3
66	WLD-IDEAL	5	4	2	2	3	5	4	4	5	1	4
82	AMG-RRPL6C	2	3	3	5	4	?	?	3	5	3	4
83	AMG-RRPL7C	2	3	3	5	4	?	?	3	5	4	4
84	AMG-DRAWC	2	3	3	5	4	?	?	3	5	3	4

Stable Pool Alternatives												
56	RES-FULPL	4	2	1	2	3	4	4	4	1	2	4
57	RES-WRT	3	2	3	4	3	5	4	4	2	3	3
58	RES-MAX	3	2	2	4	3	5	4	4	2	2	3
59	REC-OPTP	3	1	1	3	3	5	5	4	2	1	4
60	REC-OPTF	4	5	2	3	3	5	3	4	2	2	4
61	REC-ACC	3	4	2	3	3	5	4	4	2	1	4
62	IRR-OPT1	4	2	2	4	3	4	4	4	1	1	4
63	IRR-OPT2	4	2	2	4	3	4	4	4	1	1	4
64	IRR-OPT3	4	2	2	4	3	4	5	4	1	1	4
65	RES-IRRFLO	5	2	1	3	3	2	3	5	1	1	5
67	WLD-REAL	4	4	3	3	2	5	5	3	5	2	3
68	AMG-POOL	3	2	2	4	3	5	4	3	2	2	4
69	AMG-POOL2	3	3	2	4	2	5	4	3	2	2	4
70	RES-SWAP	3	2	2	4	3	5	5	3	2	2	3
71	RES-COMP	3	2	2	4	3	5	5	3	2	2	4
72	RES-FLD	4	3	2	4	3	3	4	4	2	2	4
73	RES-PECT	3	2	2	4	3	5	5	4	1	2	4
74	REC-OPTP2	3	1	1	2	2	5	4	4	2	1	4
75	REC-OPTF2	3	4	2	3	2	5	3	3	2	2	4
76	REC-ACC2	3	4	2	3	2	5	3	4	2	1	4
89	RES-IRRFLO2	5	2	1	3	3	2	1	5	1	1	5

Power Alternatives												
77	PWR-CPMAX	1	4	3	4	3	5	4	2	2	3	3
78	PWR-AVOP	1	4	3	4	3	4	5	3	2	3	3
80	AMG-CORPS/BOR	1	3	3	4	3	4	4	3	2	2	3
81	AMG-CAN	1	3	3	4	3	4	4	3	2	3	3

PROCESS

There are many ways to interpret the quantitative and qualitative information produced during the screening phase to compare or contrast alternatives. Thus, the team used several different approaches in appraising the screening results. Several of the work groups completed their own examination of the screening data. Each group investigated ways of showing the differences and similarities among alternatives. They grouped alternatives into categories by types and size of effects. They devised their own sorting methods, and used these methods to compare and group them.

For the project team, the process began with a 2-day meeting of SOR managers, work group coordinators and representatives from the cooperating agencies. During screening, alternatives were assigned to five groups based on the operational characteristics as follows:

1. Base Case Operation — alternatives representing base case conditions
2. Flow Augmentation — alternatives modifying flow requirements for fish
3. Drawdown — alternatives involving Snake River reservoir drawdown
4. Stable pools — alternatives stabilizing reservoir elevations
5. Power — alternatives changing power system planning and operation

Within these groupings, the project team used the numerical results of screening to further sort the alternatives by the river use effects into distinct categories. For example, several of the lower Snake River drawdown alternatives resulted in similar benefits to anadromous fish while showing minimum effects to recreation and resident fish. Additionally, wildlife was slightly affected and serious impacts to navigation occurred. These alternatives formed one category within the drawdown grouping. There were other stable pool alternatives that produced benefits to recreation, resident fish, anadromous fish, wildlife, irrigation and cultural resources but had large impacts to power. Likewise, they formed one category within the stable pool alternative.

By finding that alternatives could be grouped into categories of effects, the team concluded that each category might represent a single operating strategy. However, some of the categories did not suggest a strategy but rather suggested specific elements that could be added to other, more distinct operating strategies. Therefore, the team developed the candidate SOSs using a variety of screening information, including the categories identified through the above process and qualitative factors not reflected in the numerical results. Other regional activities influenced several strategies, such as the Corps' System Configuration Study and the National Marine Fisheries Service's Endangered Species Act and Recovery Plan processes.

CANDIDATE SYSTEM OPERATING STRATEGIES

The following describes the candidate SOSs that the team proposes be carried into the full-scale analysis phase of SOR. Each SOS description is numbered and includes a title. General elements that characterize the operation are listed. These elements will be refined as the strategies are further developed and evaluated in full-scale analysis. The screening alternatives that illustrate the strategy and will be used as a starting point for further development of the strategy are listed. Explanatory observations and comments are also presented.

SOS 1 — Post-Regional Act with ESA and 1992 Options EIS Operations (No Action Alternative)

Elements of Operation:

- Operating strategy reflected in 1992 (or most current planned operations).
 - John Day Reservoir to 262.5 feet, filled as needed for irrigation.
 - Snake projects to within 1 foot of MOP.
 - additional water budget flows from Dworshak of 900 KAF in the spring, 270 KAF in July, and 200 KAF in September.
 - 137 KAF is released from Brownlee via outflow increases during July and returned to storage by increases in inflow from Upper Snake release.
 - Up to 3.0 MAF of additional water for the flows on the Columbia would be stored in Arrow and Grand Coulee if the January to July runoff forecast is 80 MAF or less, and no storage if the forecast is 90 MAF or more. Between 90 and 80 MAF, storage would vary from 0 to 3.0 MAF, depending on the forecast. Only Coulee and Arrow would be affected by this operation. This action would be treated operationally rather than put into firm planning.
- Consists primarily of the operation suggested in the NPPC's Phase II amendments to their Fish and Wildlife Program. Operation for 1992 was modified from this program through ESA consultation with NMFS.

Screening Alternatives used as starting points for this SOS:

- AMG-92EIST, AMG-WASH, AMG-NPPC1, and AMG-NPPC2.

Observations/Comments:

- The alternatives evaluated in screening did not reflect operations as they actually took place in 1992.
- Changes to the 1992 operations developed through the 1993 Supplemental EIS on river operations, ESA consultations, or other processes will be incorporated.
- Screening results for some of alternatives in this category showed limited impacts in most river use areas on a system-wide basis, however, some individual reservoirs had larger impacts.

SOS 2 — Natural River Operation

Elements of Operation:

- Drawdown of lower Snake River projects to natural river levels.
- Depth of drawdown is 78 feet or more, depending on flow.
- New open-channel flow outlets would be constructed at each dam.
- Power generation would not occur.

- Refill options are natural inflow and storage.
- Flow augmentation would not be required.
- Duration of drawdown options are 2 months (April 16 through June 15) and 4 1/2 months (April 15 through August 31).

Screening Alternatives used as starting points for this SOS:

- ANA-EMI

Observations/Comments:

- There are potentially several other physical modifications possible which use this operation. The System Configuration Study (the Corps' investigation of project modifications to benefit anadromous fish) is developing these physical drawdown alternatives.
- Power costs determined in SOR screening do not reflect capital costs that may be required for dam reconfiguration.
- Resident fish are likely to experience major habitat losses from drawdown alternatives. These losses are not captured in the screening model.
- Anadromous fish screening models do not adequately treat drawdown alternatives. There is significant uncertainty about the adequacy of data to accurately estimate biological benefits which would occur at flow velocities which would be achieved with drawdown.

SOS 3 — Fixed Drawdown to below MOP

Elements of Operation of Operation:

- Drawdown of lower Snake River projects to below minimum operating pool.
- Depth of drawdown options are 33, 43, and 57 feet.
- Power generation would continue.
- Refill options are natural inflow and storage.
- Flow augmentation options are none (pre-water budget operation of storage projects), 1991-92 operations, and new storage plus 1991-92 operations.
- Duration of drawdown options are 2 months (April 16 through June 15) and 4 1/2 months (April 15 through August 31).

Screening Alternatives used as starting points for this SOS:

- AMG-RRPL6C, AMG-RRPL7C, AMG-DRAWC (with generation).
- AMG-RRPL6B, AMG-RRPL7B, AMG-DRAWB (without generation).

Observations/Comments:

- The System Configuration Study is evaluating drawdown depth, drawdown duration, refill and flow augmentation options for this alternative.

- Power costs determined in SOR screening do not reflect capital costs that may be required for dam reconfiguration.
- Resident fish are likely to experience major habitat losses from drawdown alternatives. These losses are not captured in the screening model.
- Anadromous fish screening models do not adequately treat drawdown alternatives. There is significant uncertainty about the adequacy of data to accurately estimate biological benefits which would occur at flow velocities which would be achieved with drawdown.
- Fixed drawdown would permit use of open-channel juvenile fish bypass systems.

SOS 4 — Drawdown Below MOP to Meet Target Velocities of Flow

Elements of Operation:

- Drawdown of lower Snake River projects to below minimum operating pool (MOP) to achieve a particular flow-velocity equivalent.
- Depth of drawdown would range down to 57 feet.
- Power generation would continue.
- Refill options are natural inflow and storage.
- Flow augmentation options are none (pre-water budget operation of storage projects), 1991-92 operations, and new storage plus 1991-92 operations.
- Duration of drawdown options are 2 months (April 16 through June 15) and 4 1/2 months (April 15 through August 31).
- Flow-velocity equivalent targets are CBFWA-suggested levels during drawdown. CBFWA-suggested flow targets for the Snake River are also used in other months.

Screening Alternatives used as starting points for this SOS:

- ECN-NPPC85, ECN-CBFWA and ECN-CBFWAMOD

Observations/Comments:

- The System Configuration Study is evaluating drawdown depth, drawdown duration, refill, flow augmentation, and hydro system firm load options for this alternative.
- Power costs determined in SOR screening do not reflect capital costs that may be required for dam reconfiguration.
- Resident fish are likely to experience major habitat losses from drawdown alternatives. These losses are not captured in the screening model.
- Anadromous fish screening models do not adequately treat drawdown alternatives. There is significant uncertainty about the adequacy of data to accurately estimate biological benefits which would occur at flow velocities which would be achieved with drawdown.

- Variable drawdown would probably require the use of pressurized conduit juvenile fish bypass systems.

SOS 5 — Spring Flow Augmentation with Guaranteed Power Operation

Elements of Operation:

- Federal power system is guaranteed 90 percent of its 1990-91 firm hydro energy load carrying capability. Regional loads to be met by the hydro system are reduced by 900 MW in every month except May and June (9,000 MW-months).
- System operates on upper rule curves unless drafting is necessary to meet reduced load or to meet flow targets below. Secondary market is eliminated.
- Flow targets (kcfs) are as follows:

	Critical Lower Granite	Average Lower Granite	Critical Priest Rapids	Average Priest Rapids
APR2	60	75	120	120
MAY	80	100	140	140
JUN	60	80	120	140
JUL	40	50	110	100
AUG1	35	35	90	100
AUG2	35	35	90	100

- Modified flood control operation (new Upper Rule Curves) at Libby, Hungry Horse, Dworshak and Brownlee to reflect a variable outflow requirement, as a function of water supply forecasts, during flood control refill. In an average year, the system flood control space requirement for the four projects is reduced by at least 20 percent.
- Drawdown to at least minimum operating pool at lower Snake and John Day (262.5 feet) projects with a 1.5 foot operating range.

Screening Alternatives used as starting points for this SOS:

- AMG-FEE with elements of AMG-IRRFLO and FLD-VARQ2

Observations/Comments:

- This strategy attempts to model a different way of operating the river system. The federal power system is guaranteed 90 percent of the firm energy produced by current operations. Other river users control the rest of the system and may operate it as they see fit, as long as it doesn't jeopardize meeting the power system's requirements. As currently defined, this strategy provides spring and summer flows for anadromous fish, but the general concept could be applied to system operations for other uses as well.

SOS 6 — Target Flows for Anadromous Fish Year Round

Elements of Operation:

- Flow targets are based on the runoff forecast or other factors, but would exist for all months.

- Realistic, attainable targets for all water conditions, particularly critical water, need to be determined by hydroregulators and anadromous fish experts.
- May include consideration of new storage to allow system to meet higher targets.

Screening Alternatives used as starting points for this SOS:

- ANA-STEP1 to STEP5, AMG-CBFWA, AMG-CBFWAMOD, ANA-4YRFDST1

Observations/Comments:

- Results of screening would be used to help set target flows for this strategy. Particularly valuable for setting targets during the critical period may be the alternatives which developed critical rule curves for fish (e.g. ANA-4YRFDST1).
- Screening alternatives generally showed improved conditions for anadromous fish at the expense of resident fish, recreation and cultural resources at storage projects.
- This SOS would strive toward CBFWA flow targets, particularly under high runoff conditions but would recognize the need to have lower targets in dry years to preserve refill and other future operational needs of the fish.

SOS 7 — Stable Storage Reservoirs Elevations with Near Natural Flows

Elements of Operation:

- Storage reservoirs are kept at target elevations less than full based on biological rule curves. The biological curves are incorporated, taking into account inflow forecasts to allow for flood control drafting, as a compromise for resident fish goals.
- Storage reservoirs pass approximately natural inflows.
- In the event of flooding, the storage reservoir is filled and then released in a control fashion until the original elevation target is again reached.

Screening Alternatives used as starting points for this SOS:

- ANA-FU1C, ANA-FU1B, RES-FULPL, RES-IRRFLO, RES-FLD, RES-IRRFLO2

Observations/Comments:

- Most alternatives screened involved holding storage reservoirs full year round. RES-FLD is the exception; it held levels less than full to provide some flood control space.
- Most screening alternatives in this group were also run assuming Canadian reservoirs were held at stable elevations. Since this violates the scope of the SOR, Canadian reservoirs would not be held at stable elevations in this strategy.
- Summer migration for anadromous fish is not modeled and may be affected adversely by alternatives in this group.
- Some of these alternatives cause flooding in recreation and cultural resource sites downstream, an impact not captured by the screening models.

SOS 8 — Storage Reservoirs Filled in Late Spring

Elements of Operation:

- Reservoirs are filled by May 31; reservoirs are not drafted until October 1.
- Eliminates water budget/flow augmentation requirements, but keeps other nonpower-power requirements.
- Spring flows are used to fill the reservoirs.
- No drafts below refill curves occur for power production.
- Reservoirs are filled to the following elevations:

Brownlee	2077 ft.
Dworshak	1600 ft.
Chief Joseph	954 ft.
Grand Coulee	1288 ft.
Albeni Falls	2062 ft.
Libby	2459 ft.
Hungry Horse	3558 ft.

Screening Alternatives used as starting points for this SOS:

- REC-OPTP, REC-OPTP2, IRR-OPT1, IRR-OPT2, IRR-OPT3, AMG-POOL, AMG-POOL2.

Observations/Comments:

- Power costs are uniformly less for this SOS than for the SOS which keeps reservoirs at stable elevations all year long.
- Although spring flows are adversely affected (which impacts spring migrating anadromous fish), summer flows are improved which should help summer runs.
- Impacts to anadromous fish could be reduced with non-instream migration techniques, such as transportation.

SOS 9 — Pre-Regional Act Operations

Elements of Operation:

- Uses operating criteria established prior to implementation of the Fish and Wildlife Program following adoption of the Regional Act.
- Uses current load shapes and maintenance schedules. Considers changing maintenance schedules to further optimize power production.
- Eliminates the water budget, spill agreements and Vernita bar agreement.
- Keeps current refill requirements.

Screening Alternatives used as starting points for this SOS:

- PWR-CPMAX

Observations/Comments:

- This operation would reflect how the Columbia River system could be operated today if there were no special requirements for fish and wildlife. It removes water budget operations, spill agreements, and other fish measures.

SOS 10 — National Marine Fishery Service (NMFS) Recovery Plan

Elements of Operation:

- Unknown until identified by the Recovery Team.

Screening Alternatives used as starting points for this SOS:

- Unknown

Observations/Comments:

- This SOS is a placeholder and may not represent a unique operation. One of the previous nine candidate strategies may capture the Recovery Team's recommendation and in that case, this SOS would be eliminated.

NEXT STEPS

The strategies proposed in this chapter are only candidates for discussion and development into a final set of alternatives. By presenting the candidates here, the team is seeking to broaden the review and development of the SOSs. The SOR team is looking for involvement in refining, changing, deleting or adding to these strategies before the team begins full-scale analysis. The result of this broad public review will be the selection of strategies that the team will present and analyze in the Draft SOR Environmental Impact Statement, scheduled for release in 1993.