Independent Scientific Advisory Board
for the Northwest Power and Conservation Council,
Columbia River Basin Indian Tribes,
and National Marine Fisheries Service
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Memorandum (ISAB 2014-3) **June 23, 2014**

To: ISAB Administrative Oversight Panel
Bill Bradbury, Chair, Northwest Power and Conservation Council
Paul Lumley, Executive Director, Columbia River Inter-Tribal Fish Commission
John Stein, Science Director, NOAA-Fisheries Northwest Fisheries Science Center

From: Robert J. Naiman, ISAB Chair

Subject: Review of the Fish Benefits Workbook for the U.S. Army Corps of Engineers' Willamette Valley Project

Background

This is the first of a two-part ISAB review associated with the Willamette Project, the U.S. Army Corps of Engineers' operated system of 10 high-head[1] federal dams and reservoirs, three run-of-river dams that function as re-regulating projects, and 42 revetments located in Willamette River tributaries. The Bonneville Power Administration (BPA) is responsible for marketing and transmitting power generated from 8 projects, with the remaining projects being non-power producing facilities. The U.S. Bureau of Reclamation (BOR) administers a water marketing program for water stored in Corps' reservoirs to agricultural users.

The ISAB's two-part review covers the Fish Benefits Workbook (FBW) and life-cycle modeling developed by the Corps, NOAA Fisheries, and other agencies to inform the Corps' Configuration and Operations Plan, which is to be completed by December 2014. This first review is of the FBW, which is designed to help evaluate alternative approaches to improving downstream passage at dams and associated reservoirs in the Willamette River Basin. The ISAB's second review, an evaluation of the life-cycle model, is due August 1, 2014. The ISAB's reviews are intended to provide constructive feedback to the Corps, NOAA Fisheries, and their cooperators as they complete analyses supporting the Configuration and Operations Plan. This review is a logical next step from the ISAB's recent review of NOAA's life-cycle model for the Federal

[1] "High-head" – The elevation change from forebay to the average tailwater ranges from 360' to 450' feet and reservoir water surface elevations fluctuate by as much as 160' annually at WP dams creating significant challenges for developing fish passage improvements.

Columbia River Power System Biological Opinion (FCRPS BiOp) (ISAB 2013-5) and the ISRP's Review of the Research, Monitoring, and Evaluation Plan and Proposals for the Willamette Valley Project (ISRP 2011-26).

The Corps, NOAA Fisheries, and agency representatives participating in the Willamette Action Team for Ecosystem Restoration (WATER) helped develop six questions for the ISAB's review. The questions are based on NOAA Fisheries' questions for the ISAB's 2013 review of the life-cycle model for the mainstem Columbia and Snake basins. The Configuration and Operations Plan's work relates to reintroduction of anadromous fish to areas blocked by high-head federal dams – an issue that is being discussed basinwide, especially regarding the Columbia River Treaty.

ISAB Answers to the Six Review Questions

1) Are the specific approaches and methods scientifically sound? Are there any significant conceptual flaws?

The FBW User Guide (FBW) presents the logic of the model and provides examples and calculations on how the model partitions fish passage through dams under different outlet options and reservoir elevations. The FBW's basic structure appears to be scientifically sound, and the factors being considered in the model appear to be comprehensive. The project participants have a thorough knowledge of the structure of each dam and how fish pass around these structures. The accounting framework is quite sophisticated and well organized. The reductionist approach also seems well suited to this application, but the reliability of survival estimates likely will be limited by the paucity of empirical data to parameterize the model. Assessing overall survival outside the scope of the FBW is likely to present bigger conceptual and scientific challenges.

2) Do the models make appropriate use of available data; and provide an appropriate framework to incorporate new data over time throughout the implementation of the BiOp?

The FBW appears to use all the relevant data that are available. However, the data are limited, especially for some projects and some parameters of interest. This deficiency is addressed by applying data collected at other Willamette projects to locations without data or using expert opinion when no available data were deemed appropriate. There is relatively little justification provided as to why certain data sets are used to represent conditions at projects without project-specific data. For example, passage survival values of Chinook using the turbine and regulating outlet routes at Green Peter Dam are based on corresponding estimates for Chinook using those routes at Cougar Dam whereas passage survival values for Chinook using the spillway at Green Peter Dam are based on estimates for rainbow trout passing over the spillway at Detroit Dam. No rationale is provided as to why these data sets are considered the most appropriate to represent passage survival at Green Peter Dam. It is not clear why expert opinion is used for spillway survival values for Chinook at Hills Creek Dam rather than using trout spillway survival rates from Detroit Dam as they were for the Green Peter and Lookout

Point/Dexter projects. Clarification of the basis for selection of data sets for the projects is needed.

The FBW provides a framework for incorporating new data, provided the data are in a format compatible with the model. However, the Alden memo[2] indicates that some modifications to the model are not possible because of its current structure. For example, the model assumes that route effectiveness is fixed regardless of reservoir level. However, the memo indicates that it is likely that route effectiveness will change as reservoir level drops and the openings for the turbine and RO get closer to the water surface. This change could have an impact on overall survival rate by routing a higher proportion of the fish through routes with higher mortality. However, this change in route effectiveness with water level currently cannot be captured by the model. The Alden memo also points out several other components of the FBW that do not fully align with the current understanding about fish passage dynamics and project configuration. Addressing these issues in future versions of the FBW could improve the reliability of the project survival estimates.

The models could be useful to look at potential climate change scenarios because operational and configuration changes that may seem to work under current climate conditions may not be suitable for future regime changes. However, because the Reservoir System Simulation model (ResSim) is currently being run for the 73-year historical period, it may not be possible for the FBW model to adequately incorporate flows that occur under climate change.

3) Are the data sufficient to build and make effective use of the model? If not, what types of data need to be collected to answer the question and develop the model? Can the model be a predictive model, or should it just be used to compare the relative effects of alternatives?

As noted above, project-specific survival data for many age classes of Chinook and steelhead are not available for many of the projects. The extent to which the application of data from other dams influences the accuracy of the survival estimates is not known. However, the influence on accuracy could be considerable given the magnitude of variation in parameter values among dams. The reliability of the modeling effort would be improved if these data gaps were filled.

Data for survival of certain size classes of fish also are lacking. For example, route-specific survival data for Chinook fry (<60mm) are not available because these fish cannot be tagged. The FBW assumes that passage survival of Chinook fry is equivalent to the upper end of the 95% confidence interval for passage survival of Chinook yearlings. Justification is needed for this assumption.

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[2] Alden BioAnalysts Inc 2014, "Willamette River Fish Benefit Workbook Parameterization: Chinook," Technical Memo, 01 April 2014. U.S. Army Corps of Engineers, Portland District, Oregon.

The FBW does not appear capable of being a predictive model at this time but could be useful in ranking project operations if model uncertainties are adequately defined. A more complete assessment of uncertainties associated with modeling (including the ResSim model) and data collection is needed. It is important to note that the FBW output for comparing relative survival benefits and ranking alternatives being considered could be in error for those projects that have very little dam-specific or age-class specific data.

Even if the FBW is effective at representing the relative benefits of the alternatives, these results alone cannot be used to identify the most beneficial management alternative without evaluating the effect of each option on full life-cycle survival and the impact on viable salmonid population (VSP) parameters; highest dam survival may not always have the most beneficial impact on population recovery. The environmental consequences of reservoirs created by the dams have not been adequately evaluated. Some of the alternatives being proposed include significant drawdowns in reservoir elevation to induce migration and increase dam passage survival of fry and sub-yearlings. Survival past the dams may be increased, but eventual survival may ultimately decrease if the habitats the fish encounter below the dams are not as productive as their home reservoir. Developing a better understanding of the influence the reservoirs have on Chinook and steelhead population performance will not be an easy task. The fact that the reservoirs differ in physical habitat, food availability, and predation risk requires collection of project-specific information. A better understanding of the influence of reservoirs and downstream conditions on fish survival and growth is needed before identifying appropriate restoration actions. Appendix C in the Alden Chinook memo suggests how rearing capacity of the reservoirs could be assessed. The approach has merit, but there will clearly be a need to collect data on the availability of suitable habitat at various pool elevations. These data will be needed to populate the Ecosystem Diagnosis and Treatment (EDT) and Cramer/Beamesderfer models and to validate their scenarios. Similar work is needed in habitats below the dams to assess the carrying capacity of those locations.

Collecting project-specific survival data is the greatest information need for the FBW. The sensitivity analysis provided in the Alden memos provides some indication of the specific parameters that have the most influence on total project survival and should be the initial focus of data collection efforts. Perhaps a ranked list of the relative importance of future data, including which project specific parameters would be most useful, is needed. However, as the ultimate goal of this entire effort is to generate estimates of VSP responses to the application of various project management alternatives, the data needs of the FBW may not be the most critical knowledge gap. Care needs to be taken when coupling FBW survival results with the Species Life-cycle Analysis Modules (SLAM) to estimate VSP parameters because high passage survival may not translate into high survival to another life stage.

4) Are the documents provided clearly written? Are the methods described in sufficient detail for a reader to understand and replicate what was done? Are assumptions and uncertainties about the analyses clearly described? For example, do the authors identify the strengths and weaknesses of the model and its inputs, and accuracy and precision of model output?

The Willamette Configuration and Operations Plan biological analysis document clearly summarizes the context for the FBW and the objectives of the ISAB review. The FBW manual and the Alden memos are well written and contain excellent graphics to aid in understanding the structure of the FWB model. Many acronyms are used, so a glossary would be very useful.

The full suite of parameter values, and the sources from which these were obtained, are provided in the Alden memos that serve as the primary source for documentation on the models. These reports clearly describe assumptions and uncertainties, and the reports provide a thorough and fair assessment of weaknesses in the methods and data available for model parameterization.

Results of alternative scenarios are provided in well-organized spreadsheets. Section 3 of the FBW User Guide and Appendix A of the Alden Chinook memo has detailed examples of the computations for the FBW that are very helpful in understanding how the model works. Section 4 points to a series of YouTube videos demonstrating how to use the FBW in a relatively easy to understand manner. A written synthesis and interpretation of the results would be useful, especially for some readers who may find the spreadsheets difficult to comprehend.

One of the goals of the FBW is to compare the impact of alternative operations and configurations on dam passage survival. The sample documentation of the FBW results from a proposed change in operations or configuration is quite complete and will allow reconstruction and audit of the estimated effects from proposed changes, for example, *Fish Benefits Workbook Documentation, Chinook Alternatives, South Santiam Subbasin – Foster* (FOS_Doc_042314.pdf).

More information on the ResSim model is needed in Section 3.3.1, such as performance verification/calibration, and conditions that were simulated. That is, it is necessary to have a few sentences, or a short appendix, that justify using the ResSim inputs.

In addition, a stand-alone document should be prepared to provide a readily available description of the verification of ResSim. It is understandable that full calibration and validation may not be possible for the ResSim model, but there should be a reference that describes how the use of its output is appropriate and the caveats for assumptions or limitations of the models should be discussed. Because the FBW is dependent on the inputs from ResSim, it is important to have an understanding of the model's uncertainties and how they may affect FBW results. If possible, some runs should be made that replicate actual operations at each reservoir to verify that the model does reasonably represent flows or estimate model errors.

Editorial comments:

- The definition of DPE on page 2 of the FBW User Guide is confusing. The definition says that it is a function of reservoir elevation, but then the formula does not appear to include elevation. Should "forebay entrance" be "forebay entrance elevation"? If not, what are the units of forebay entrance? Is it a volume based on water surface elevation?
- Are there different efficiencies of the FSO (page 4 of FBW User Guide) at different water surface elevations? If so, are FSOs modeled with these different efficiencies?

- More explanation of Figure 1 on page 5 of the FBW User Guide is needed. Will all readers know what HOR represents, what the solid black line represents, what the little blue rectangles represent?
- More explanation of Figure 5 on page 12 of the FBW User Guide would be useful. Perhaps the caption could explain that “Flow” means that fish distribution is proportional to flow.
- The caption and content of Figure 6 of the FBW User Guide is inconsistent with the citation in the text at the bottom of page 26.
- In the Alden Chinook memo, there are two tables named Table 1 – page 6 and page 10.
- Also in the Alden Chinook memo, the parameters listed on page 2 and on page 9 are not the same. The parameters should be stated the same throughout.
- The flow diagrams and following text in Appendix A of the Alden Chinook memo are not well connected.

5) Is the level of complexity of the models appropriate? Does the model output, characterized by metrics on initial conditions, population performance, and population dynamics, allow comparisons among populations and across scenarios within populations? Did they conduct appropriate sensitivity analyses?

The FBW is complex enough to provide flexibility for estimating relative dam passage survival rate under a wide range of scenarios. Typically, not enough empirical data are currently available to warrant such complexity, but the FBW also provides a systematic foundation for exploring the potential value of collecting additional data.

The FBW describes a complex model that tries to integrate, on a daily basis, the water arriving at the dam, the effects of structures and operations on water passage routes, the arrival of fish at the dam, fish passage routes over the dam that are affected by operations and structures, and the juvenile survival rates by route. The model requires parameters for fish route selection and route survival that need to be applied at daily or finer time scales. Modeling in daily time steps may be needed to deal with operational changes that occur at short notice, but if data on appropriate parameter values are not available on a daily basis, then the reliability of simulated results is questionable.

Data for many parameters appear to be unavailable at fine resolution, and so approximations are used that may defeat much of the advantage of using a complex model. For example, arrival of fish at the structure is determined by monthly proportion and then allocated within a month, either proportional to flow or uniform across the days within a month (See Figure 5 of User Guide). While using the estimated proportion of fish that arrive at the forebay by month may seem reasonable, splitting this number of arrivals uniformly by day is a simplification apparently caused by a lack of appropriate data. This can lead to unstable boundary conditions, for example where the estimated number of fish arriving at the dam suddenly jumps at monthly boundaries. This could result in a need for simplifying assumptions about individual parameter values. Comment 14 (Appendix I, Alden Chinook Memo) also remarks on this conflict among realism, complexity, and data limitations.

An explanation of the rationale for detailed modeling at the daily level would be useful. Presumably, a complex model is needed because of the ability to rapidly change dam operations that will affect fish passage. However, operational changes may occur within a day, such as peaking operations. Fish passage also may vary during the day due to diurnal patterns in movement. However, if daily smoothing is deemed appropriate for this level of variation, then perhaps weekly or biweekly smoothing would be adequate. If the daily scale is desired, then a plan is needed on how to obtain sufficient data to reliably estimate the parameters in the model.

The passage efficiency and survival parameters are treated as density independent. It is possible that there also could be a density dependent element to these variables, such that the efficiency or survival changes depending on the number of migrants approaching the dam. A consideration of relevant density dependence work in the region is recommended.

The Alden memos indicate that a limited sensitivity analysis was undertaken by varying individual parameters in a one-at-a-time fashion between high and low values. The sensitivity analyses are not extensive, but they do evaluate the effect of using parameter values at the upper and lower range of plausible values, with parameters manipulated individually and all together (the “best” and “worst” case scenarios). This is helpful in determining which parameters appear to have greatest impact in the current model structure. This one-at-a-time method assumes that there are no interactions between changes in parameters. Some additional runs using the most sensitive parameters would be useful to see if combinations of high and low parameter values tend to cancel out the impacts of individual parameters when considered one-at-a-time. The manner in which the results of the sensitivity analyses are presented implies a linear relationship between the high and low values, which may be incorrect. Additional sensitivity runs using more than two parameter levels are recommended.

6) The Configuration and Operations Plan analysis approach will apply FBW and SLAM outputs to estimate VSP scores to evaluate biological benefits (e.g., population extinction risk, population viability) of alternative actions to reduce WP effects in order to address the ESA. Biological analysis results will be evaluated with cost, other non-monetized effects, feasibility, implementation timing, and uncertainty/risks for a range of alternatives. Considering your review of the above questions, do you concur with the biological analysis approach for the stated purposes?

The FBW estimates juvenile mortality that occurs between the forebay and tailrace of individual dams. Relative ranking of management scenarios will be helpful in prioritizing potential actions, but extensive monitoring and evaluation will be needed to validate outcomes. The stated purpose of using results from FBW in conjunction with other factors (SLAM and VSP models) to determine implications for overall population viability has merit but may be difficult to implement into practice. This stepwise approach to estimating overall survival has obvious computational advantages, but some operational scenarios explored in the FBW (e.g., those involving reservoir level) might change components outside the scope of the FBW that, in turn, create changes in components of the FBW. Care will be needed to properly account for such interactions between FBW and SLAM. Another factor to consider in the connecting FBW, SLAM, and VSP is mortality that is related to route of passage but does not occurs until after fish leave the tailrace.

Use of weighting factors may be necessary in order to rank and prioritize the alternatives under review. One might imagine that a particular passage option that provides high survival rates but is difficult and costly to implement would be less attractive than a less costly, more readily implemented method that provides slightly lower passage survivals and VSP benefits. In other cases, an incremental implementation of alternatives may be desirable. For example, a less effective alternative might be readily employed and used until a more desirable one could be implemented. Those kinds of decisions and other trade-offs should be identifiable using a prioritization process that examines and weighs the multiple facets of each alternative. Comprehensive monitoring and evaluation programs should be put in place to validate expected results. Some flexibility should also be incorporated into the process. If for example it becomes clear that the expected benefits of an operational regime are not being realized or that a new method may provide greater benefits, it should be possible to revisit and change how operations are conducted.

Computing benefit-cost ratios will be challenging. In population viability analyses, it is typically more feasible to compare the relative performance of different management scenarios than to estimate absolute values of survival or extinction risk under those scenarios. Consequently, recommendations about the relative ranking of management options to achieve desired outcomes will be more credible than absolute estimates of benefit-cost ratios and extinction probabilities.