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<u>MEMORANDUM</u>

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	Kathy Tackley, COE	EIS, Water Quality Technical Group
	Sara Marxen, COE	EIS, Hydrology Technical Group

FROM: Michele DeHart/for the CSS Oversight Committee

DATE: October 5, 2017

RE: Comparative Survival Study models, model inputs model outputs

Following the Comparative Survival Study (CSS) presentation to the Fish Technical Group on September 21, we have summarized responses to questions provided prior to the September 21 meeting as well as questions asked during the meeting. The following is a brief description of CSS models discussed with the work group, as well as CSS modelling inputs, outputs and evaluation metrics. The presentations provided at the meeting are accessible by selecting the CRSO/EIS tab at http://www.fpc.org/documents/CSS.html.

Following is a brief description of CSS modelling structures, inputs, outputs and resulting metrics used to evaluate alternatives. The Fish Technical Group questions are presented in bold font followed by our response.

<u>Models used in CSS analyses</u>

The models used in CSS analyses are Empirical Statistical models. The models make statistical inferences between hydrosystem and ocean variables (e.g. water transit time, powerhouse passages (PITPH) ocean conditions) and dependent variables (e.g. juvenile in-river survival, juvenile travel time and smolt-to-adult return rate (SAR)). The models are based upon hydrosystem and fish passage monitoring data for the Columbia and Snake rivers collected through 2016. In addition to the models that have focused on the Passive Integrated Transponder

(PIT) tag data, analyses have been conducted using run reconstruction data. These models incorporate additional data such as spawner recruit data from 1968 through 2013 (life cycle model), and population data from tributaries of the Grande Ronde River. These analyses have detected similar relationships between environmental variables and dependent variables, despite their differences in methodology and life-stage focus, providing cross-validation support between models.

The CSS analyses produce survival and other response metrics that span one or more stages of salmonid life history. In-river survival and fish travel time estimates span the entire hydrosystem from mainstem entry to Bonneville Dam. SARs are calculated from project to project (e.g., LGR-GRA, LGR-BOA, BON-BOA) and represents survival through the hydrosystem, any delayed hydrosystem effects on survival in the marine environment, and independent marine environmental effects on survival. Consistent with the structure of empirical statistical models, the survivals implicitly capture all sources of mortality within the life stage of the metric. The sensitivity to environmental variables is empirically evaluated from the historical data. Historical time series of environmental variables are used to evaluate associations with the response variables, and these associations are used to generate predictions of those responses under future environmental conditions. The current set of models reflect the refinements that have been regionally reviewed and implemented over more than ten years of analyses focused on attributing variation in survival and other response metrics to environmental and hydrosystem management factors, and as such have culled out many factors that do not explain substantial variation not already accounted for with the most statistically significant explanatory variables.

Lifecycle Model

The CSS life cycle model evaluates survival over the full life cycle from spawning adult to adult return. It does so by predicting variation in several life-stage specific survivals in relation to environmental variables in the freshwater mainstem Columbia and Snake rivers and ocean variables. The case study reported in the CSS 2017 annual report provides estimates of model parameters that predict life-stage-specific survivals for Snake River spring/summer Chinook. Mainstem and ocean survival estimates may be applicable to other Snake spring/summer populations than the ones used in the case study, but would require knowledge of spawner to smolt relationships. Applicability to fall Chinook and upper Columbia spring and summer Chinook populations would depend on data availability to repeat the analyses for those populations. Lower river and ocean components of survival may be transferrable from the Snake to the upper Columbia.

Juvenile Fish Travel Time Models

These models characterize the associations between juvenile fish travel time and environmental conditions. Model results for Chinook and steelhead indicate that fish travel time is expected to improve (i.e. faster fish travel times) as water transit time and powerhouse passage encounters are reduced. Fish travel times also tend to be faster later in the migration season than earlier in the migration season.

Juvenile Survival Models

These models characterize associations between environmental conditions and juvenile survival. Model results for both Chinook and steelhead indicate that juvenile in-river survival is expected to increase as water transit time and powerhouse passage encounters are reduced. These models also indicate that juvenile survival is expected to decrease with increases in Julian date (i.e., cohorts out-migrating early in the season tend to survive at higher rates than their later-timed counterparts). The life cycle model also predicts juvenile in-river survival, but rather than isolating the analysis to the juvenile stage, it balances the estimation of juvenile in-river survival with the estimation of juvenile production and ocean survival. The isolated juvenile survival analyses and life cycle analysis predict similar relationships between hydrosystem conditions and in-river survival.

Ocean Survival Models

These models characterize the association between ocean survival and freshwater environmental variables such as water transit time, Julian day, PITPH, and ocean variables, such as the Pacific Decadal Oscillation (PDO), ichthyoplankton indices, and upwelling. For both Chinook and steelhead these models indicate that ocean survival is expected to increase with reductions in water transit time and reduction of powerhouse passage encounters as represented by the PITPH variable. For both species there was a slight negative effect of increases in Julian date on ocean survival. Increases in spring upwelling and ichthyoplankton biomass and cooler PDO levels are expected to increase ocean survival of both species. The life cycle model also predicts ocean survival, but rather than isolating the analysis to the ocean stage, it balances the estimation of ocean survival with the estimation of juvenile production an in-river survival. The isolated ocean survival analyses and life cycle analyses predict similar relationships between hydrosystem, ocean conditions and ocean survival.

Smolt-to-adult Return models

These models characterize the associations between environmental conditions and Smolt-to Adult Return rates (SARs). These model results indicate that, for both Chinook and steelhead, SARs are expected to increase with reductions in water transit time and the number of powerhouse passage experiences as represented by the PITPH variable. These models indicate that SARs are expected to decline with increasing Julian date and that increases in spring upwelling and increases in ichthyoplankton biomass are expected to increase SARs. The life cycle model predicts SARs as a direct calculation from life cycle returns predicted from in-river and ocean survivals. Life cycle and SAR models predict similar relationships.

Transported: In-River (TIR) models

These models characterize the associations between environmental conditions and the ratio of Smolt-to-Adult return rates for Transported versus In-River migrants, a ratio referred to as TIR. These models indicate that, for both steelhead and Chinook, TIRs are expected to decline with reductions in water transit time and reductions in the number of powerhouse passage encounters, as represented by the PITPH variable.

Model inputs
Inputs required for evaluating operations alternatives are, daily flow for each mainstem Columbia and Snake rivers projects, daily flow over the spillway for each project, daily water temperature at each project, daily forebay elevation for each project, and a clear description of each of the operational alternative.

Responses to questions provided prior to the September 21 meeting.

Timeline Considerations

- **Are there any modeling elements still in development? If so, when will these be ready?**
  No there are no modeling elements that are presently under development.

- **Do you have capacity to conduct the modeling work? We're looking at 12-15 alternatives, ready for runs as early as March 2018.**
  Models of fish travel time, in-river survival, ocean survival, SARs, and TIRs have been developed and can be applied to evaluate alternatives provided that the input variables for each alternative have been specified (e.g., project-specific estimates of daily flow, spill proportion, water temperature and forebay elevations). Similarly, life cycle analyses can be performed for any alternative provided that the input variables conform to the input structure used to perform life cycle reconstructions and projected performance metrics in the CSS 2017 annual report. At the September 21 meeting we provided the analyses and model outputs for 24 operational alternatives. These 24 operational alternatives included spill under the present BIOP operations, spill to the 115%/120% gas cap, spill to the 120% gas cap, and spill to the 125% gas cap at present project configuration. Each of these four alternatives was modeled with and without breach of the four lower Snake River projects. Finally, each of these eight alternatives was modeled at three different flow levels: high, medium, and low. The ability to provide modelling analyses of other alternatives depends upon the specifications of the operations alternatives.

- **What information/support do you need from us?**
  As discussed in the previous question, to generate predictions of response metrics under a set of alternatives we need daily estimates of project-specific flow, spill proportion, water temperature and forebay elevation. The life cycle model is currently set up to use spawners at age 3-5, smolts, harvest rates, powerhouse passage in year of migration, water travel times, PDO, upwelling, in-river survival rates, SARs for transport and in-river migrants, and the combined aggregate SAR. These files must be supplied for each of the inputs, along with assumptions about future environmental conditions, flow, and spill. Files would need to conform to specific formats (e.g., metadata and data for each information input). In order to generate the required life cycle inputs we need the federal work groups to provide daily flow, spill proportion, forebay elevation, and water temperature at each project for each alternative.

- **With recent PIT tag releases of UCR summer Chinook, are sufficient data available to adapt the model to include UCR summer Chinook without significant delay in the modeling schedule?**
  At the present time the CSS and SMP projects generate juvenile survival, juvenile travel time and SAR data for Upper Columbia stocks. Models for juvenile fish travel time and juvenile survivals from Rock Island Dam to McNary Dam have been developed and could be applied to evaluate alternatives. To date, we have not developed a life cycle model for the Upper Columbia projects. PIT tag detection of juvenile migrants is very limited at the Upper Columbia Public Utility projects.

Metrics/Outputs

- **What are the outputs (metrics)? Species covered?**
  The CSS has developed models that examine five response metrics that include juvenile fish travel time, juvenile survival, ocean survival, SAR and TIR, as well as life cycle survival (i.e., spawning adult to adult return response metrics). The species covered include spring/summer Chinook salmon, fall Chinook salmon, sockeye salmon and steelhead. The spatial and temporal scale of those response metrics varies by species. Life cycle model outputs are stage-specific life cycle abundances. The life cycle model currently tabulates adults returning to spawn and the SAR to Lower Granite for each population in the Grande Ronde River. Other metrics (e.g., geometric mean recruits per spawner, probability of exceeding abundance threshold) can also be extracted from the model, but would require modest additional development

- **To what extent may UCR summer Chinook, Fall Chinook or sockeye be covered?**
  Juvenile fish travel time and juvenile survival models for sockeye salmon from Rock Island Dam to McNary Dam have been developed. SARs have been calculated for wild summer Chinook from the Okanagan River for the MCN-BOA and RIS-BOA reaches for 2011-2014. SARs have been calculated for UCR wild sockeye from the Okanogan and Wenatchee rivers for juvenile migration years 2013-2015. Given the limited duration of these SARs, it is not possible to develop SAR models for these groups. SARs have been calculated for wild, Hanford Reach fall Chinook salmon for migration years 2000-2014. Models for SARs of Hanford Reach fall Chinook have not yet been developed. The life cycle model was calibrated to the Grande Ronde/Imnaha spring/summer Chinook MPG. If spawner to smolt relationships are established for other Snake spring/summer Chinook MPGs, the model could be applied to those populations, making it almost a directly transferable analysis. For UCR populations, it would require making some assumptions about the common in-river survival effect of the lower four Columbia River dams. This would not account for the effects of hydrosystem operations upriver of McNary dam, but may explain the PITPH effect of the shared migration portion of the Columbia. The UCR would not be a directly transferable analysis.

- **If applicable, what's the difference in outputs between your specific module and your full LC model?**

  The CSS life cycle model is a "full" LC model. It predicts smolts, in-river and transport migrants entering the ocean, and 3-5 year old adults entering the Columbia, arriving at LGR dam, and returning to spawn.

- **What is the geographic scope of the model? Does it include the upper Columbia River (Chief Joseph Dam downriver)?**
  The CSS life cycle model was developed and applied to Snake River spring/summer Chinook and parameters were estimated based on the mainstem and ocean variables that affected survival through each life stage. Population reconstructions were found to be very sensitive to powerhouse passage through eight hydropower projects that juvenile salmon and steelhead migrated through, as well as water transit times, PDO, and upwelling. Since upper Columbia Chinook experience only 4 dams in common, (McNary, John Day, The Dalles and Bonneville) the life cycle model would reasonably only be sensitive to the lower four dam fraction of the 8 Columbia and Snake rivers projects. This would not account for the effect of the Upper Columbia powerhouse passage through the Public Utility District projects. Indices of powerhouse passage through the Upper Columbia dams have not been developed. If powerhouse passage indices were developed and similar data and environmental variables were available it may be possible to adapt the life cycle model to the upper Columbia.

Model Relationships/Scope of Analysis

- **Will your model(s) be able to adequately model the full range of alternatives (no action, structural and operational actions, dam breaching) under various water years (i.e. low, median and high)? Would models need significant changes to reach this point?**
  The CSS has developed models that examine five response metrics that include juvenile fish travel time, juvenile survival, ocean survival, SAR, and TIR as well as life cycle survival (i.e., spawning adult to adult return) response metrics. To generate predictions of response metrics under a set of alternative we need daily estimates of project specific flow, spill proportion, water temperature, and forebay elevation. For the life cycle model the CSS 2017 annual report includes alternatives of no action, three levels of increased spill for fish passage, and breach of the four lower Snake River dams under low, average, and high water years, as applied to Snake river spring/summer Chinook.

- **If applicable, what freshwater metrics drive the survival relationships (sensitivity analysis, or just conceptually) in your model(s)? What other non-freshwater relationships drive your model(s)?**
  The CSS has found that freshwater water transit times and powerhouse passage rates are important factors that influence juvenile fish travel time, juvenile survival, ocean survival, SARs, and TIRs. Non-freshwater factors include indices of upwelling, ichthyoplankton biomass, and PDO. These analyses have been presented in CSS Annual Reports and CSS Annual Review meetings. For the life cycle model the spawner to

smolt relationship is predicted by Beverton-Holt productivity and capacity parameters during the freshwater life stage.

- **Are there any spill-tailrace passage, or ladder passage, relationships developed?** The CSS has conducted analyses of upstream migration success. The 2017 CSS Annual Report incudes analyses of relationships of upstream migration success relative to water temperatures and juvenile passage history. These analyses indicate that as water temperature increases, upstream survival decreases and that fish that were transported as juveniles have lower upstream migration success. Because the CSS modelling analyses are empirical statistical models, the upstream passage success, ladder passage and all other variables acting on upstream migration are incorporated into the analyses in the LGR-to-GRA smolt-to-adult return metric. The model is not dependent upon a specific relationship for each component of adult upstream migration.

- **Does the model incorporate Douglas, Chelan and Grant PUD juvenile passage operations into account to assess Alternative(s) positive or negative affects to those operations and associated juvenile survival within the Wells Dam Project area, Rocky Reach Dam project area, Rock Island Dam project area, Wanapum Dam project area and Priest Rapids project area?** The CSS has developed models of juvenile fish travel time and survival from Rock Island to McNary Dam for spring/summer Chinook, steelhead, and sockeye. At this time SAR and life cycle models have not been developed for the Upper Columbia. The CSS and SMP projects do collect and report smolt-to-adult return data through the upper Columbia projects.

September 21 meeting questions

- **Have you incorporated the effect of TDG on adult upstream migration?** Because the CSS models are empirical statistical models, the effect of TDG on adult upstream migration is implicit in smolt-to-adult return metrics because the detections account for losses from all sources of mortality, including mortality as a result of TDG related effects.

- **Have you addressed the potential impact of TDG on juvenile survival and delayed mortality?** The draft CSS Annual Report for 2017 evaluates the effect of TDG on juvenile survival and mortality rates. In those analyses there were no indications that high TDG levels reduced survival or increased mortality rates. In previous CSS modelling, TDG was added as a freshwater environmental variable. Utilizing the actual TDG that occurred in historic monitoring data, TDG did not arise as an important fresh water variable effecting juvenile survival or SARs. However, since CSS models are all empirical statistical models based upon actual historic data, the effect of TDG on all life stages is accounted for in the model outputs.

- **What have you included in the dam breach scenarios for background mortality?** CSS models are empirical statistical models. With empirical statistical models, it is not necessary to make an assumption of what background mortality would be in a breach scenario. The models we have developed could be applied to make predictions of juvenile survival between Lower Granite and McNary dams under a breach scenario. The dam breach scenarios that were presented to the Fish Technical Group assume the same background (base rate) mortality as the fully impounded hydrosystem used to estimate in-river survival rates. In the dam breach alternative scenarios we presented on September 21, we recognize that we likely underestimate the benefit of dam breach because we do not adjust for any decrease in reservoir mortality from the removal of reservoirs that is not accounted for by powerhouse and water transit time effects.