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EDMUND G. BROWN JR., Governor
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October 24, 2012

Charles Hoppin, Chair
State Water Resources Control Board
1001 I Street
Sacramento, CA 95814

Subject: Written Information Responsive to the Workshop Questions for the Bay-Delta Workshop 3 – Analytical Tools for Evaluating Water Supply, Hydrodynamic and Hydropower Effects

Dear Mr. Hoppin:

The Department of Fish and Game (Department) appreciates the opportunity to participate in the above referenced workshop. As described in its August 16, 2012 Revised Notice of Public Workshops and Request for Information, the State Water Resources Control Board (State Water Board) is requesting information related to the comprehensive Phase 2 review and update to the 2006 Water Quality Control Plan for the San Francisco/Sacramento-San Joaquin Delta Estuary (Bay-Delta Plan). The Department encloses herein information (Attachment 1) that is responsive to the questions that the State Water Board has proposed for discussion during the Bay-Delta Workshop 3 - Analytical Tools for Evaluating Water Supply, Hydrodynamic and Hydropower Effects.

Attachment 1 summarizes analytical tools to evaluate water supply, hydrodynamics and hydropower effects in the Bay-Delta, which the Department has developed, utilized or reviewed within the last decade. The Department will participate in the Analytical Tools for Evaluating Water Supply, Hydrodynamic and Hydropower Effects workshop and will continue to offer its scientific and technical expertise in an effort to assist the State Water Board in its update of the Bay-Delta Plan.

If you have any questions, please feel free to contact Glenda Marsh at (916) 445-1739 or at gdmarsh@dfg.ca.gov.

Sincerely,

Scott Cantrell

Scott Cantrell
Chief, Water Branch

Enclosure

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Workshop 3 - Analytical Tools for Evaluating Water Supply, Hydrodynamic and Hydropower Effects
Comprehensive (Phase 2) review and update to the Bay-Delta Plan

California Department of Fish and Game
Attachment 1

The Department of Fish and Game (Department) submits the following comments in response to the State Water Resources Control Board's (State Water Board) August 16, 2012 revised notice which requests information to be discussed in Workshop 3 – *Analytical Tools for Evaluating Water Supply, Hydrodynamic and Hydropower Effects* – associated with the Phase 2 review and update of the *2006 Water Quality Control Plan for the San Francisco/Sacramento-San Joaquin Delta Estuary* (Bay-Delta Plan). The Department's mission is to manage California's diverse fish, wildlife and plant resources, and the habitats upon which they depend, for their ecological values and for their use and enjoyment by the public. Our comments are based on the Department's mission and specific areas of expertise.

The State Water Board poses two questions to be addressed in Workshop 3. The questions are: (1) what types of analyses should be completed to estimate the water supply, hydrodynamic and hydropower effects of potential changes to the Bay-Delta Plan, and (2) what analytical tools should be used to evaluate these effects and what are the advantages, disadvantages, and limitations of these tools. In response to the first question, the Department discusses some of the types of analyses the State Water Board should complete and recommends that these analyses include the use of conceptual, environmental, biological, and population and life history models to assess how changes in potential water supply, hydrodynamic, and hydropower operations may impact fish and wildlife resources.

In response to the second question, the Department identifies analytical tools it has developed, utilized, or reviewed. The Department notes that it has not provided a comprehensive list of all the tools available for modeling the effects of potential changes to the Bay-Delta Plan and acknowledges the existence of other generally accepted models for water supply management. With this response, the Department chose to identify analytical tools that it has developed or has significant experience utilizing, such as SalSim 2.0 and HEC-5Q, for assessing impacts on fish and the habitat upon which they depend. In addition, the Department identifies some of the analytical tools the State Water Board may consider to estimate water supply, hydrodynamic, and hydropower effects and presents the limitations of these tools' utility for addressing impacts to fish and wildlife resources. Table 1 - *Summary of Analytical Tools for Evaluating Water Supply, Hydrodynamic and Hydropower Effects* – includes a brief assessment of the analytical tools identified by the Department.

The Department strongly recommends that the State Water Board use the SalSim 2.0 model to consider potential changes to the Bay-Delta Plan. As explained further below, the Department has been developing this population and life history model since 2005. Department staff will be available to present SalSim 2.0 to the State Water Board to facilitate its consideration and use. In addition, the Department is available to assist the State Water Board with the evaluation of other models it may consider using to assess the environmental, biological, and fish population impacts of water operations and alternatives in proposed revisions to the Bay-Delta Plan. For example, the Department has a working group for Central Valley salmonids that can review models or analyses for Chinook salmon and steelhead.

Regarding application of water supply and hydropower models, such as CalSim-II, the Department recommends forming an operations modeling group that includes technical modeling staff from the State and Federal fish agencies and interested non-governmental organizations. In addition, the Department respectfully requests that all models used by the State Water Board be available to the public in order to maintain a transparent and credible review process.

Question 1 – What types of analyses should be completed to estimate the water supply, hydrodynamic, and hydropower effects of potential changes to the Bay-Delta Plan?

Types of Analyses

The Department recommends that the State Water Board consider additional analyses beyond an analysis of effects on water supply, hydrodynamics, and hydropower to make sure that changes to the Bay-Delta Plan provide for the long-term viability of fish and the aquatic resources upon which they depend. In this regard the Department recommends that the State Board complete the following types of analyses:

- An analysis of the effects of changed diversion points (e.g., Bay-Delta Conservation Plan [BDCP]) on water supply, hydrodynamics, and hydropower.
- In assessing the effects on water supply, include an analysis of changes in water quality, including water temperature, and water supply reliability.
- In assessing the effects on Delta hydrodynamics, include an analysis of effects on movement of various fish species and life stages through the Delta and on habitat conditions.
- In assessing the effects on hydropower, include an analysis of the effects of various hydropower operations and flow alternatives on fish migration patterns, water temperature, spawning and habitat conditions, and predator abundance.
- Establish a baseline against which water supply, hydrodynamics, and hydropower effects can be compared. This baseline should include current fish protective measures.

By performing various types of analyses, the State Water Board will be able to evaluate linkages between water supply, hydrodynamics, and hydropower with more complex ecological and biological phenomena. This holistic approach will allow the State Water Board to consider not only effects on water supply, hydrodynamics and hydropower, but also the corresponding question: how do potential changes in these variables impact public trust resources?

Question 2 – What analytical tools should be used to evaluate these effects? What are the advantages, disadvantages and limitations of these tools?

The Department recommends a suite of analytical tools be considered by the State Water Board in analyzing effects. These tools generally fall into the categories of conceptual, environmental, biological, and population and life history models. Specific models with which the Department is familiar are discussed under each category further below and summarized in Table 1. The Department's response to Question 2 concludes with a discussion of how models can play a role in the adaptive management of potential changes to the Bay-Delta Plan.

Conceptual modeling tools are helpful for organizing factors and relationships based on literature into comprehensive hypotheses. Conceptual models can aid in planning and decision making by identifying key stressors and mechanisms. Such tools can serve as a starting point for developing quantitative models.

Environmental models provide insight into physical and chemical relationships. For example, water supply, or flow, is a key driver of aquatic habitat influencing the physical quality, quantity and distribution of habitat. Environmental modeling tools can provide insight into the relationship of flow to parameters such as water temperature, turbidity, depth and velocity.

Biological modeling tools are needed to understand the influence of flow on more complex components such as migration and spawning success of Chinook salmon. Population and life history models are required to understand the relative importance of multiple biological factors and assess incremental effects on particular aquatic species of interest. The use of biological or population and life cycle models requires very explicit statements of the question(s) the model is designed to address and the resolution of the biological, spatial and temporal data used to generate output from these models. When using these modeling tools, the inputs, assumptions, and limitations must be clearly documented before attempting to rely on modeling outputs to inform decisions or policies. Furthermore, in building a complex, multivariate model it is important to consider the potential increase in uncertainty and variance introduced with the addition of each new parameter. Caution is also needed before attempting to extrapolate findings of models developed for a particular life stage, species, or region to different questions, species, or geography.

Conceptual Models

Conceptual models are "abstractions of reality created to express a general understanding of a more complex process or system" (Fischenich 2008). Conceptual models use diagrams, narratives and/or tables to represent a set of causal relationships. Conceptual models can be used to express a working hypothesis about the form and function of the ecosystem, and the relationships between its components

(Gross 2003). Quantitative models, including both statistical and process models, are more valuable than conceptual models in many situations (DiGennaro et al. 2012), but conceptual models are critical when quantitative models are not available, and can provide a conceptual basis for the development of quantitative models. Clearly articulated conceptual models that specify key state variables, describe their dynamic interrelationships, and project consequences of alternative management actions are a key critical component of adaptive management (Walters 1986).

Advantages of using conceptual models are that they can:

1. Facilitate communication. Conceptual models are a tool through which detailed technical concepts can be summarized qualitatively to audiences with a range of technical expertise.
2. Integrate knowledge across disciplines. Conceptual models provide a background upon which scientific information (e.g. ecology, chemistry and geology) can be integrated with the perspectives of multiple stakeholders with alternative views.
3. Increase understanding. Conceptual models help users understand the often complex processes in a system (e.g. how things work, what drives these things and major impacts) and demonstrate the links between them.
4. Identify knowledge gaps. Conceptual models can help users identify any gaps in scientific understanding. They can be updated to incorporate new information, and thus can serve to track and integrate the best available science.
5. Identify performance measures, monitoring metrics and quantitative modeling priorities (Gross 2003; Fischenich 2008; DiGennaro et al. 2012).

Delta Regional Ecosystem Restoration Implementation Plan (DRERIP)

A formalized approach to the development of conceptual models for the Delta has been developed under the auspices of DRERIP, a component of the Ecosystem Restoration Program (ERP). The Department is currently involved in the process of prioritizing the update and publication of existing models, and the development of new models, and recommends their use in reviewing and implementing the Bay-Delta Plan. Two types of conceptual models have been generated under the ERP: species life history, and ecosystem models for processes, habitats, and stressors. The models were designed to identify and characterize the current level of understanding, importance, predictability, and character and direction of the effect of cause-and-effect relationships between ecological driver variables and ecosystem and species response variables; this structure is termed a “Driver-Linkage-Outcome” format (DiGennaro et al. 2012). The models were developed by subject experts, including agency scientists, academics, and private consultants, and each model underwent peer review. Three models (Sedimentation [Schoellhamer et al. 2012], Juvenile Salmon [Williams 2012], and Floodplains [Opperman 2012]) and a paper concerning the use of conceptual models and decision support tools to guide restoration planning and adaptive management (DiGennaro et al. 2012) were recently published in San Francisco Estuary and

Watershed Science, a peer-reviewed online journal at http://escholarship.org/uc/jmie_sfews.

The DRERIP conceptual models are part of a formal scientific evaluation process that also includes an action evaluation procedure and a decision support tool, designed to evaluate proposed restoration actions in the Delta within an adaptive management construct. The DRERIP scientific evaluation process, including conceptual models, was used previously to evaluate conservation measures proposed by the BDCP (Essex Partnership 2009). The application of the DRERIP scientific evaluation process to this planning effort was intended to provide technical input and insights that could refine the draft conservation measures. The scientific evaluation process will be used this month (October 2012) to evaluate a broad suite of conceptual design alternatives that have been proposed for the Prospect Island Tidal Restoration Project, a project being implemented jointly by the Department of Water Resources (DWR) and the Department under the Fish Restoration Program Agreement (FRPA).

The DRERIP scientific evaluation process represents an important tool that can be utilized by the State Water Board during the update of the Bay-Delta Plan. For example, several of the DRERIP conceptual models are directly relevant to the State Water Board's investigation regarding establishment of water quality standards for flow or other flow-related requirements to support inundated floodplain in the Bay-Delta watershed (State Water Board 2009). These include: Floodplain, Mercury, Fish Habitat Linkages, Splittail, and Salmon. These models can be used in conjunction with available quantitative models (e.g..hydraulic and hydrodynamic models) and the action evaluation procedure to evaluate potential positive and negative outcomes, estimate overall degree of worth and risk, and assess reversibility and opportunity for learning associated with alternative floodplain habitat flow objectives. Additional information regarding the DRERIP conceptual models, and the models themselves, is available online at: http://www.dfg.ca.gov/ERP/conceptual_models.asp.

Pelagic Organism Decline (POD)

The conceptual models developed by the Interagency Ecological Program (IEP) over the course of the POD investigation, which revolve around natural and anthropogenic drivers that affect ecological changes including the observed pelagic fish declines (Sommer et al. 2007, Baxter et al. 2010, U.S. Bureau of Reclamation [USBR] 2012) are also relevant to the update of the Bay-Delta Plan. For example, the species-specific POD conceptual models focus on the suite of drivers thought to be most important for that particular species (Baxter et al. 2010) and may prove to be useful in evaluating potential changes due to revised water quality objectives. The regime shift model places the POD into a more historical ecosystem context and sets the stage for a new phase of the POD investigation (Baxter et al. 2010). The insights gained from the species-specific and regime shift models can also be used to inform the review and update of the Bay-Delta Plan's monitoring and special studies program.

Environmental Models

CalSim-II

CalSim-II was jointly developed by USBR and DWR to compare monthly benchmark conditions versus other operational alternatives for the Central Valley Project (CVP) and State Water Project (SWP) systems. It can be used to understand the impacts of alternative system operations at various levels of development and for different water demand scenarios. It is a simulation model that assumes good decisions have been identified and implemented from among all possible and feasible decisions.

The Department's primary recommendation regarding application of water supply models, such as CalSim-II, is that the tool(s) needs to be vetted through a modeling workgroup that includes technical modeling staff from the State and Federal fish agencies and interested non-governmental organizations. This technical modeling group, in coordination with State Water Board staff and consultants, would develop and/or refine the modeling tools used to analyze questions of effect on water supply and other relevant beneficial uses including those for aquatic life.

Specifically related to the Department's recommended adaptive management approach to achieve biological objectives, the following are some limitations of CalSim II and recommendations to address these limitations:

1. CalSim-II is a monthly model, so biological analysis requiring instantaneous high or low flows must be evaluated externally. While there are many different methods by which this post processing could be accomplished, the specific approaches should be developed and selected within the modeling group recommended above.
2. While CalSim-II was designed to analyze CVP and SWP operations, it is not a detailed operations model and does not capture many of the complexities of forecasted and actual operations of project facilities. Operations of non-State or non-Federal reservoirs and water right diversions are not implemented in as fine of detail. Changes either in magnitude or timing of river flow at upstream projects will alter the inflow to the CVP and SWP projects. This should also be addressed in the modeling group.
3. CalSim-II operational goals, for the purpose of considering environmental flows, must be constrained to consider both short-term and seasonal ramping of flows both up and down. If additional large volumes of water are going to be released from points in the system to increase total flows in the Delta, the local impacts of changes to seasonal flow patterns need to be considered. Project specific impacts, including potential short-term and seasonal shifts in the timing of releases, as well as the effects to hydropower beneficial uses for upstream facilities, should be evaluated using reservoir simulation or project operations models developed for each specific project.

HEC-5Q

In the mid-1980s the US Army Corps of Engineers developed HEC-5Q in order to model and optimize reservoir operations to meet water quality objectives (Willey 1986). HEC-5Q can also be used to evaluate concerns such as flood control, hydropower, water supply and irrigation diversions. HEC-5Q is available for both the San Joaquin and Sacramento River watersheds.

i) San Joaquin River Watershed

The Department has applied HEC-5Q as the basis for its own San Joaquin River Basin-Wide Temperature Model. The model is used to simulate various flow, storage and diversion regimes while analyzing thermal and hydropower impacts. The Department is working to update the model with data through December 31, 2010. This work is nearly completed and will simulate flow on a daily basis, temperature at 6-hour intervals, electrical conductivity at key locations, and hydropower generation. The Department is currently using the model to evaluate flow scenarios and temperature simulations in the three tributaries (Merced, Tuolumne and Stanislaus) and mainstem from the Merced River confluence downstream to Mossdale on the San Joaquin River. The Department provided an earlier version of the model and training to State Water Board staff for their use in evaluating the temperature impacts of flow alternatives.

The Department uses this model, along with current flood storage criteria, primarily to evaluate whether river temperatures at different flows are suitable for fall-run Chinook salmon. Each fall-run Chinook salmon life stage, from egg to adult, thrives at a different temperature. The Department will use the model to evaluate how modifying historical flows affect river temperatures during juvenile rearing and out-migration periods. With juvenile salmon leaving the system as late as June, the Department intends to use the model to evaluate the flows necessary to drive sufficiently cool temperatures to allow these emigrating juvenile Chinook salmon to successfully migrate out of the system. Impacts on storage and diversions are also analyzed.

Advantages of HEC-5Q include the ability to simulate various flow scenarios and evaluate resulting temperatures, electrical conductivity and hydropower generation. Since the model predicts temperatures on a 6-hour time step, the approximate daily maximum and minimum temperatures can be evaluated. The Department's San Joaquin River Basin-Wide Temperature Model will be released to the public in the near future. As stated earlier, the Department will use the model to evaluate impacts related to fall-run Chinook salmon, but this model could be utilized to evaluate thermal impacts on any thermally sensitive species.

Limitations of this particular version of HEC-5Q include the fact that it was developed specifically for the San Joaquin River (i.e. mainstem to Millerton Reservoir) and its three main tributaries (i.e. Stanislaus, Tuolumne, Merced Rivers and their lower rim dam reservoirs). In addition, HEC-5Q is a one-dimensional model that assumes quantities are the same across both the width and depth of a river system. Certainly, floodplain and other shallow or eddy areas might have elevated temperatures that are not calculated in the model. Another limitation of this version of HEC-5Q is that actual daily maximum and minimum temperatures might not be simulated within the 6-hour time step interval.

ii) Sacramento River Watershed

Between 1997 and 2005, USBR sponsored development of the following two HEC-5Q models for the Sacramento River System: 1) a temperature only model including Trinity, Lewiston, Whiskeytown, Shasta and Keswick reservoirs and the Sacrament River downstream to Knights Landing; and 2) a model that extended from the Red Bluff Diversion Dam to Knights Landing and included Sites Reservoir, the GCID and TCC canals and the Colusa Drain. This second model included a wide range of water quality parameters. During the past year, the temperature only model has been extended to include the Sutter Bypass system and the Feather and American Rivers. The representation in the model of the Sacramento River has been extended to Freeport. This extension includes Lake Oroville, the three Thermalito reservoirs, Folsom Lake and Lake Natoma. It is the Department's understanding that this extension is not complete but should be finalized early next year.

Department staff do not have specific experience with the Sacramento River version of HEC-5Q, but the development efforts for both the San Joaquin and Sacramento River models were undertaken by the same consultant with whom Department staff are familiar. The advantages and limitations of this version of HEC-5Q are similar across the two watersheds.

Biological Models - Delta

Delta Passage Model (DPM)

The DPM is being developed by Cramer Fish Sciences and is a component of the full-life cycle Integrated Object-oriented Salmon-simulation (IOS) model. The DPM uses survival relationships based on flows and other factors to estimate through Delta survival for smolts. The Department recommends that DPM be viewed as a smolt survival model only, as it is not intended to represent younger life stages.

Flow has been determined to be an important factor in the survival of emigrating juvenile Chinook salmon. Thus, river and net flow variation and flow splits are a foundational driver of the DPM. The model uses survival data from studies that used large late-fall run Chinook salmon hatchery smolts. DPM uses current data (best available) to estimate smolt survival and migration through the Delta from the confluence of the Sacramento, Mokelumne, and San Joaquin Rivers with the Delta to Chipps Island (Cramer Fish Sciences 2012). The model compares different flow alternatives to estimate survival. In its current state, the DPM should only be used for assessing the relative survival of smolts. The model is one of the tools currently being used to compare Bay-Delta Conservation Plan (BDCP) alternatives.

Limitations of DPM include the fact that it uses survival data compiled from only late-fall run Chinook hatchery salmon, which are inherently larger than the fish the model estimates survival for (i.e. winter-run). Data from acoustic tagging studies of large (>140 mm) late-fall and San Joaquin basin fall-run Chinook smolts are the primary source of data the model uses to simulate responses (Cramer Fish Sciences 2012). However, different salmon runs move through the Delta at different sizes, water temperatures, and have different emigration timing. The DPM assumes all migrating Chinook salmon smolts respond similarly to Delta conditions. This assumption is well documented by Cramer Fish Science, but limits the specificity of model results for different runs.

Delta Smelt Abiotic Habitat Index

The final version of this model, a statistical analysis of historical data, was developed by Fred Feyrer, Ken Newman, Matt Nobriga and Ted Sommer to index delta smelt habitat in the fall season, examine trends in habitat over time, and to examine the effect of changes in habitat quality on delta smelt recruitment (Feyrer et al. 2011). The model determined that salinity and water transparency best predicted delta smelt occurrence, explaining about 26% of the total deviance. The Department believes this biological model has the advantage of using standard environmental measures collected by long-term fish monitoring programs. In addition, it is an easily implemented and relatively transparent approach.

This tool can be used to predict the quantity and quality of habitat available at a given X2 (outflow). The model identifies the biological importance to delta smelt of low salinity habitat area that also possesses moderate to high turbidity to delta smelt. The size of this habitat is sensitive to outflow as is its location (Feyrer et al. 2011); a downstream location further enhances the turbidity component via wind-wave re-suspension in the shallows of Suisun Bay.

Habitat size and sub-adult population size contribute significantly to production of the next generation. The fall habitat index describes how much abiotic habitat volume is available to the population during this important period of time when such habitat tends to be at or near an annual minimum. The Department believes that understanding the relationship between flow and fall abiotic habitat will inform management of delta smelt recruitment.

Limitations of this model include that it explains only the fall abiotic habitat components (i.e., the underlying necessary physical components during a period of limitation), but not the biological components such as food or predators, which are most often identified as being important additional components of habitat.

Salvage-Density Method

The salvage-density method is an approach based on the assumption that fish catch (entrainment indexed by salvage) increases linearly with effort (pumping rate). It is a simple tool that was used most recently in early versions of the BDCP Effects Analysis to evaluate the effect of CVP and SWP southern Delta water exports on fish salvage levels at the export facilities. The Department believes this method is more useful when looking at the relationship between salvage and exports at the CVP, because the CVP generally exports water 24 hours a day directly from Delta channels, not through a forebay. This reduces complications associated with variable export rates and predation within the forebay experienced at the SWP. With these and the following considerations in mind, the Department believes this method is most useful for reconnaissance-level assessments.

The approach uses historical estimates of (typically) monthly fish salvage density (salvage estimates divided by the associated volume of water exported) to estimate salvage rates under different export scenarios. Entrainment loss projections made from salvage estimates can be “normalized” using species abundance where such measures are available. The approach has been used in previous project assessments of the Delta-Mendota Canal/California Aqueduct Intertie project and early assessments of BDCP effects.

The major limitations and constraining assumptions of the salvage-density method are related to not including factors that can influence entrainment and salvage such as turbidity, predation rates on non-salmonids in Clifton Court Forebay, and pumping rates. In addition, because the method relies on historical estimates, it cannot predict salvage outcomes of future project scenarios or assess the results of new real time management efforts. Further, the salvage-density method does not appear to consider other factors such as pre-screen loss or louver efficiency that contribute to an increase or decrease in salvage other than exports.

The model is a simple tool that can be used for looking at seasonal trends in salvage of species covered under the BDCP, but as stated in background materials provided by the federal resource agencies for a BDCP review by the Delta Stewardship Council, this method is inferior to that of Kimmerer (2008, 2011) whose approach estimates proportional population losses. This background information can be accessed at: http://deltacouncil.ca.gov/science-program/bdcp-effects-analysis-review-materials-supporting-information-and-presentations.

Kimmerer Proportional Entrainment Method

Kimmerer (2008, 2011) developed approaches for estimating proportional annual entrainment of adult and, separately, larval and juvenile delta smelt, as well as Chinook salmon smolts emigrating from the Sacramento River at the CVP and SWP water export facilities in the southern Delta. The Department recommends the adaptation and use of the Kimmerer (2011) method for the purpose of developing and evaluating the effects of alternative flow objectives during the update and revision of the Bay-Delta Plan because it also addresses Chinook salmon smolts emigrating from the Sacramento River. A distinct advantage of the Kimmerer approach over other entrainment estimation methods is that the product (proportional entrainment) directly addresses the magnitude of entrainment loss relative to population size. For the time periods examined (2002 through 2006 for adults, and 1995 through 2005 for larvae and juveniles) estimates varied widely. However, for both life stages entrainment losses could be very substantial and total annual losses could approach 40%.

The Kimmerer (2008) method for estimating adult delta smelt proportional entrainment uses the observed relationship between Old and Middle River (OMR) flow and entrainment (an expansion of salvage) in combination with population estimates based on IEP's Kodiak Trawl Survey. His method for larval and juvenile delta smelt uses OMR along with the density of smelt at IEP 20mm Survey stations in close proximity to the export facilities relative to the density of delta smelt system-wide. Miller (2011) and in response Kimmerer (2011) have subsequently further explored the assumptions associated with the original approach (Kimmerer 2008).

Kimmerer's analysis was intended as a retrospective look at proportional entrainment for the years and life stages he examined, not as a predictive tool. However, as has been done for versions of the BDCP effects analysis, the method can be adapted for the purposes of examining the effects of alternative project operations or protective schemes.

Abundance-X2 regression models (longfin smelt example)

The longfin smelt abundance- X2 model (Kimmerer et al. 2009) is an update and a refinement of the longfin smelt abundance-X2 regression presented by Jassby et al. (1995) and of an earlier version by Kimmerer (2002). These references also provide a suite of abundance-X2 models for various other estuarine organisms. The Department supports use of this model because it allows for a step-change in 1987 resulting from the effects of the introduced clam *Potamocorbula amurensis*, while generating a rough estimate of the likely abundance outcome of providing a particular amount of winter through spring outflow.

The model describes the relationship between the mean position of X2 in the January through June period (see Kimmerer 2002) and longfin smelt abundance in the subsequent Fall Midwater Trawl survey: the lower the X2 location, the greater the abundance. Outflows that move the location of X2 downstream also produce more low salinity habitat (Kimmerer et al. 2009) and increased net surface flow (Monismith et al. 2002) for downstream transport of larvae (Dege and Brown 2004). Hypothetically, the outflow-associated turbidity may also benefit larvae by reducing predation, particularly from emigrating juvenile salmonids (personal communication, Randall Baxter, Department of Fish and Game, email September 9, 2012).

The model estimates longfin smelt (or other organism) abundance response to X2, which itself is correlated to a suite of conditions associated with enhanced outflow including increased volume of low salinity habitat for rearing, increased turbidity that may reduce predation, enhancements to the food web due to nutrient transport, and inhibition of clam grazing. The models in Kimmerer et al. (2009) incorporate direct and indirect outflow effects on longfin smelt, bay shrimp, and starry flounder as well as presumed upstream conditions affecting splittail and American shad. The models are quick to implement and useful for evaluating species responses to changing flow conditions during each species' relevant life stage period.

A limitation of the current model is that it does not account for the longfin smelt abundance decline associated with the POD in the early 2000s (see Thomson et al. 2010). A better overall data fit can be obtained by accounting for stock size based on a two-year lag in abundance indices in addition to outflow (see longfin smelt section of Baxter et al. 2010). This refinement is being developed by the U.S. Fish and Wildlife Service (USFWS) and the Bay Institute and appears to provide a more certain prediction of the longfin smelt abundance response to Delta outflow (or X2 placement) during the winter-spring period.

Population and Life History Models – Sacramento River Basin

In addition to the models described below, the Department recommends the use of the Delta smelt life history model, developed by the USFWS and the life-cycle model for winter-run Chinook salmon, developed by the National Marine Fisheries Service for evaluating the effects of alternative proposals for objectives for the Bay-Delta Plan.

Sacramento Ecological Flows Tool (SacEFT)

SacEFT, developed by the Nature Conservancy (TNC) with funding from the Calfed Bay-Delta Program and Resources Legacy Fund Foundation, is a decision analysis tool used to evaluate effects of water supply management on the needs of anadromous fish and other Sacramento River riparian and aquatic species (TNC 2008). The Department supports using SacEFT for evaluating alternatives proposed for the Bay-Delta Plan and their effects in the Sacramento River eco-region.

SacEFT was developed to evaluate the ecological consequences of management-related changes in flow regime (TNC 2008). Examples of water supply management applications targeted for evaluation by SacEFT are the Shasta Lake Water Resources Investigation and the North-of-Delta Off-Stream Storage Investigation. In addition, SacEFT is considered in the BDCP effects analysis to assess upstream winter run Chinook salmon spawning and egg incubation habitat conditions under different flow regimes (ICF 2012).

Advantages of SacEFT include its use of established and accepted models such as CalSim-II along with ecological submodels for meander migration, gravel augmentation and sediment transport, all of which are influenced by flow. SacEFT relates these additional attributes of the flow regime to multiple species' life-history needs, thereby contributing to understanding of water operations on representative sets of the model's focal species and their habitats (Chinook salmon, steelhead, green sturgeon, bank swallows, channel erosion/migration, Fremont cottonwoods, and large woody debris recruitment). This provides the capability to analyze ecological trade-offs under different operational scenarios. In addition, when any of these models advance or change, SacEFT can still be applied to the latest information (ESSA Technologies Ltd. 2011).

Because SacEFT simulations rely on CalSim-II-SRWQM (Sacramento River Water Quality Model) output data it incurs the following limitations:

1. If the time-step required to evaluate ecological effects of management actions (such as additional water storage facilities) is finer than what can be reflected by CalSim-II-SWRQM output, the ecological effects analysis in SacEFT will be based on a level of precision not adequate to reflect the actual flow regime.
2. CalSim-II functions on a monthly time-step.
3. The built in assumptions of CalSim-II are carried over to the SacEFT model.

If refinements in reservoir operations and coldwater management (that include real-time management) are required for decision-making, more precise flow regime data is required. The outputs from CalSim-II cannot be used to model time-steps finer than monthly without relying on synthetic (disaggregation) techniques developed by DWR (TNC 2008). SacEFT is capable of simulating higher precision flow data once those physical datasets become available (TNC 2008).

Population and Life History Models – San Joaquin River Basin

SalSim 2.0

SalSim has been under development since 2005 (Model Version 1.0) by the California Department of Fish and Game and has been peer reviewed twice, once in 2007 and again in 2012. The Department's response to the 2007 peer review was submitted to the State Water Board in 2008 along with the first updated model version (1.5). The 2012 peer review, and the Department's response to peer review, will be released in the near future when this version of the model is released to the public. In summary, model version 2.0 utilizes empirical data from the San Joaquin River watershed to predict how changes in a variety of environmental factors (both flow and non-flow) impact Chinook salmon populations. Because of this model's specificity, use of empirical data, and peer reviews, the Department believes it will have great utility to the State Water Board for evaluating impacts of Bay-Delta Plan alternatives for both the Phase I and Phase II reviews pertaining to reevaluating adequacy of instream flows standards in the San Joaquin River basin.

This life cycle model (V.1.0) began as a fairly simple spreadsheet designed to identify the magnitude, duration and frequency of spring flows needed at Vernalis to achieve specific Chinook salmon population goals within the San Joaquin River watershed. While the earliest version of SalSim provided support for the Department's flow recommendations at Vernalis (Marston 2005), new questions arose as to the relative importance of other, non-flow factors on Chinook salmon populations. The Department's flow recommendations were revised upon release of model version 1.6 in 2009.

Due to peer review comments received, SalSim has evolved into version 2.0, a substantially more complex model, containing greater resolution in the inland, delta, and ocean ecosystems comprising salmon life history to provide insight into the effects of changes not only in flow, but also water temperature, water quality, predator abundance, ocean conditions, harvest and superimposition of redds on Chinook salmon populations.

Multiple factors influence salmon survival within, and across, inland, delta, and ocean ecosystems. In order to address the issue of what flow standards should the Bay-Delta Plan require to support juvenile fish life stages and production, the Department assembled all relevant empirical data and parsed them into various life cycle modules. These modules include: Inland Tributary Juvenile Production and Movement, Inland Mainstem Movement, Juvenile Delta Survival, Ocean Survival, Adult Homing Escapement, Hatchery Strays, and Adult River Entry Timing and Spawner Distribution.

The Department is currently completing SalSim 2.0 updates to prepare it for public release. To ensure transparency, the Department's public release of the model will include the model itself (V.2.0), model documentation, model coding, model quality assurance and quality control documentation, and both the current peer review and response to the peer review. Once the update is complete, Department staff will be available to present SalSim 2.0 to the State Water Board to facilitate its consideration and use by the State Water Board.

Hydropower Models

In order to evaluate the affects of various operational alternatives on hydropower beneficial uses, the Department recommends that the State Water Board use, in conjunction with CalSim-II, existing reservoir simulation and project operations models developed to support the relicensing of Federal Energy Regulatory Commission (FERC) projects that are located on the tributaries of the Sacramento and San Joaquin Rivers. In addition, the Department recommends forming an operations modeling group, as with application of CalSim-II, to refine and apply the modeling tools used to analyze questions of effect on hydropower beneficial uses. The following table identifies some of the models that were developed to compare the hydropower generation effects of various project-specific relicensing alternatives.

Project Name	FERC Project	Hydropower Model
Chili Bar Hydroelectric Project	No. 2155	CHEOPS & HEC-ResSim
DeSabla-Centerville Hydroelectric Project	No. 803	HEC-ResSim
Don Pedro Project	No. 2299	Spreadsheet Model[1]
Drum-Spaulding Project	No. 2310	HEC-ResSim
El Dorado Hydroelectric Project	No. 184	OASIS
McCloud-Pit Hydroelectric Project	No. 2106	HEC-ResSim
Merced River Hydroelectric Project	No. 2179	Spreadsheet Model
Middle Fork American River Project	No. 2079	OASIS
Oroville Facilities Relicensing	No. 2100	CalSim & HYDROPS
South Feather Power Project	No. 2088	CHEOPS
Upper American River Project	No. 2101	CHEOPS & HEC-ResSim
Yuba-Bear Hydroelectric Project	No. 2266	HEC-ResSim
Yuba River Development Project	No. 2246	Spreadsheet Model

Procedurally, the Department supports, as a first step, the use of CalSim-II to determine potential alternatives, from a system-wide water supply perspective, for meeting the Delta flow objectives. Because CalSim-II does not simulate the detailed operations of individual hydroelectric power projects, the second step is to apply the project-specific operations models to evaluate the effects on hydropower generation beneficial uses for each project or Bay-Delta Plan alternative.

Based on the Department’s experience in FERC proceedings over the last decade, this approach has several distinct advantages, including:

[1] Currently under development.

1. Most of the Sacramento-San Joaquin River tributaries have one or more existing project-specific operations models. Thus, model development and agency review time is significantly reduced.
2. Most of the existing project-specific operations models were developed in a collaborative process and have buy-in from a broad array of stakeholders.
3. Project-specific operations models can be used to evaluate alternatives in specific tributaries without necessarily needing to perform new simulations for the entire Sacramento-San Joaquin River Delta. For example, the impact to project-specific hydropower generation associated with shifting releases from the Feather River system to the Yuba River system can be evaluated by simply simulating the alternative flow schedules with the HYDROPS model on the Feather River and the HEC-ResSim and spreadsheet models on the Yuba River.

The State Water Board's notice identified Plexos for Power Systems, a proprietary power market optimization model (available at http://energyexemplar.com/), as a potential analytical tool that could be used to evaluate the affects of various operational alternatives on hydropower beneficial uses. The Department recommends that if it is used by the State Water Board to evaluate Bay-Delta Plan alternatives, this model will need to be made publicly available so that the Department and others can evaluate the model's applicability and results. This includes the model itself and all of the underlying assumptions necessary to evaluate the effects of various operational alternatives on hydropower beneficial uses.

Table 1 – Summary of Analytical Tools for Evaluating Water Supply, Hydrodynamic and Hydropower Effects

Model	Description	Benefits	Limitations	Type
DRERIP	Utilizes current level of understanding to rank and predict nature and direction of cause-and-effect relationships.	Peer reviewed and includes individual fish species and habitat functions. Identifies drivers/stressors and mechanisms.	Outputs are qualitative assessments.	Conceptual
POD	Identifies natural and anthropogenic drivers of ecological change, such as abrupt decline of pelagic fishes	Summarizes understanding of factors that may have contributed to the POD and inform development of research studies.	Outputs are qualitative assessments.	Conceptual
CalSim II	Planning model simulates operations of CVP and SWP.	Based on historical record. Long history of use. Covers wide range of hydrologic conditions.	Monthly time steps - to get biological effects must perform additional analyses. Does not address non State or non-Federal projects. Assumes good decisions.	Environment
HEC-5Q	Used to optimize water operations to meet water quality objectives.	Can incorporate multiple variables including storage, flows, water temp, and power.	The Department's calibrated version is restricted to the San Joaquin River Basin. One-dimensional, update with 2010 data still ongoing.	Environment
Delta Passage Model	Predicts relative survival of smolts migrating thru Delta	Biological basis (successful fish migration) for comparing BDCP alternatives.	Assumptions based on migrating hatchery fall-run Chinook. Smolt survival model only.	Biological
Delta Smelt Abiotic Habitat Index	Used to predict quality and quantity of delta smelt habitat.	Methods have been peer reviewed. Includes regression on observed data.	Based on only two abiotic factors (salinity and water transparency). Covers only part of Delta and only during the fall.	Biological
Salvage-Density Method	Uses historic salvage and flow data to predict entrainment.	Numerous data exist for all species subject to entrainment.	Assumes linear relationship between flow and entrainment. Best for assessing relative changes between scenarios.	Biological
Kimmerer Proportional Entrainment Method	Combines flow and entrainment relationships with population estimates.	Proportional entrainment takes into account size of population affected.	Not intended to be predictive tool but can be adapted to evaluate flow alternatives.	Biological

Model	Description	Benefits	Limitations	Type
Abundance-X2 regression models (longfin smelt)	Estimates annual abundance of longfin smelt using position of X2 (outflow).	Peer-reviewed methods and includes regressions based on observed data.	Recent changes in delta ecosystem and POD require update of relationships to improve fit.	Biological
SacEFT	Predicts effects of changes in flow on physical and biological parameters.	Peer-reviewed, predicts effects on multiple performance measures for fish species.	Relies on output from CalSim-II and SRWQM. Cannot be used for real time decisions given monthly time step unless more precise flow data developed.	Population Life History
SalSim 2.0	Predicts how changes in multiple environmental factors impact salmon populations.	Addresses effects of many different factors both flow and non-flow. Two rounds of peer review completed.	Most recent version still being updated. Calibrated specifically for San Joaquin River and three main tributaries.	Population Life History
FERC Hydro-project Operations models	Project specific water balance and operations models developed for FERC relicensing.	Can build on system wide water balance of CalSim-II to evaluate project specific effects of flow alternatives.	Involves a multi-step process. Different hydro-projects require different model tools, thus requires understanding of multiple models.	Hydropower

The Role of Models in Adaptive Management

Adaptive management is defined in the 2009 Delta Reform Act (Water Code Section 85052) as “a framework and flexible decision-making process for ongoing knowledge acquisition, monitoring, and evaluation leading to continuous improvements in management planning and implementation of a project to achieve specified objectives”. The Department recommends that the State Water Board consider the three phase (nine-step) adaptive management framework described in the Final Staff Draft of the Delta Plan (Appendix A, Delta Stewardship Council 2012). The implementation of an adaptive management program related to fall outflow (i.e., Fall Low Salinity Habitat [FLaSH], USBR 2012), pursuant to the requirements of the USFWS’s (2008) biological opinion, represents a recent noteworthy example. The Department provided additional information regarding adaptive management in its submittals to the State Water Board pertinent to Workshops 1 and 2, dated August 16, 2012 and September 20, 2012, respectively.

An adaptive approach provides a structured process that allows for making management decisions under uncertain conditions using the best available science, closely monitoring and evaluating outcomes, and re-evaluating and adjusting decisions as more information is acquired. Based on adaptive management principles, delaying action (e.g., revising flow objectives) until more information is available is not advisable or warranted given the best available scientific information and the condition of public trust resources. The Department concurs with the following statement made by the Invited Science Panel during Workshop 2 – “Rather than waiting for the promise of the next version of analyses or the next generation of models (in the hope that the next analysis or model will be a “break-through”), we urge the [State Water] Board to proceed with revising water quality objectives based on tools that are available now or truly imminent” (Baxter et al. 2012).

The use of models, whether conceptual, statistical, or simulation, represents a key element of adaptive management. For example, models are extremely valuable for formalizing the link between management objectives and proposed actions to clarify how and why each action is expected to contribute to those objectives. Models also provide a venue through which to identify areas of uncertainty, assess the likelihood of success, evaluate tradeoffs associated with different management actions, and define monitoring needs (Dahm et al. 2009, Williams 2011, DiGennaro et al. 2012, Delta Stewardship Council 2012). Models will be a critical component of the effort to evaluate potential resource consequences associated with alternative flow objectives, as well as during implementation of an adaptive management program associated with adoption and implementation of the revised Bay-Delta Plan.

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