Agenda Item 5a
Attachment 1

CALFED BAY-DELTA PROGRAM

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To: Phil Isenberg, Chair
Delta Vision Blue Ribbon Task Force

From: Michael Healey, Lead Scientist
CALFED Bay-Delta Program

Subject: CALFED Science Program Workshop on Delta Conveyance Modeling

On April 3, 2008, responding to a request by the Delta Vision Blue Ribbon Task Force, the CALFED Science Program hosted a workshop on hydrodynamic modeling of the Delta. The workshop was organized by Steve Culberson of the Science Program. The purpose of this workshop was to discuss various Delta hydrodynamic modeling tools and their capacity to address Task Force information needs regarding the effects of conveyance alternatives on water supply, water quality, and ecosystem. A panel of modeling experts began the workshop by presenting an overview of hydrodynamic modeling in general and its strengths and weaknesses. Representatives of Dept. of Water Resources, Public Policy Institute of California, Metropolitan Water District of Southern California, and the U.S. Bureau of Reclamation then presented more details on their specific models and modeling approaches used for simulating Delta hydrodynamics and engaged in a discussion with the panel of modeling experts about the application, strengths and limitations of their models. The panel of modeling experts has provided the Science Program with their assessment of the capability of the existing hydrodynamic models and modeling studies to address the Task Force needs for information regarding a dual conveyance system for the Delta. In assessing the value of the models discussed, the panel used the Task Force's criteria[1] as a framework. This report extracts key points from a much longer draft report of the expert panel to the CALFED Lead Scientist. Once it is finalized, the report of the expert panel will be posted on the CALFED Science Program web site.

The panel concluded that existing Delta hydrodynamic models discussed at the workshop (DSM2, RMA2, UnTRIM) when carefully and skillfully applied, can provide reliable information to the Task Force on the response of Delta hydrodynamics (water flows and water heights) to conveyance changes.

[1] Water supply reliability; seismic and flood durability; ecosystem health and resilience; water quality; projected schedule, cost and funding

DSM2 (a 1 dimensional hydrodynamic model that predicts average flows along the axis of a channel) is the most widely used model for studying water conveyance through the Delta. The model is fast and efficient and captures many of the complexities of Delta hydrodynamics. It is primarily limited by its 1D design and boundary conditions (see Table 1 for summary of strengths and weaknesses). RMA2 (a 2 dimensional hydrodynamic model that is maintained by Resource Management Associates) provides a more detailed representation of hydrodynamics, particularly in large open water areas where its 2D design allows it to simulate cross channel variations in flow that is not possible in a 1D model (see Table 1 for a summary of strengths and weaknesses). RMA2 must be combined with another model, RMA11, to provide predictions of water quality as well as flow. UnTRIM is a relatively new model developed at the University of Trento, Italy. UnTRIM is a 3 dimensional model capable of predicting cross channel and vertical as well as along channel variations in flow (see Table 1 for a summary of strengths and weaknesses). Although they give more detailed results, the 2D and 3D models require substantially more computing power and time to run. In combination, these models provide a powerful set of tools for exploring a broad range of questions about the implications of conveyance policies on Delta hydrodynamics and water quality.

Two other models discussed at the workshop, CALSIM II and CalLite, are designed to explore issues of overall water supply and allocation. These models do not deal explicitly with Delta hydrodynamics but provide critical information on inflow and exports that are input data for the Delta hydrodynamic models. CalLite, which is a simplified version of CALSIM II, shows considerable promise as a model that can be used for exploring or “gaming” a wide range of water management scenarios in the Central Valley.

In terms of the Task Force’s criteria, therefore, these models are most valuable in making predictions about the impact of conveyance on water supply.

The panel was more circumspect in its assessment of the ability of the models to predict the response of water quality variables, such as salinity, to conveyance changes. Making accurate salinity predictions is more challenging than for hydrodynamics, and some extra caution is needed depending on the problem being addressed. For example, the existing models are probably not adequate for predicting salinity intrusion as a result of sea-level rise. On the other hand, predictions of the salinity response to adding an individual gate or barrier to a particular Delta channel in the Franks Tract area should be reasonably reliable. If several gates or barriers are added, the problem becomes more difficult. Thus, existing models are useful for making predictions about water quality in relation to conveyance in some circumstances, but caution is needed in using these predictions.

The hydrodynamic models have particle tracking routines that allow some questions about the ecosystem effects of hydrodynamics to be explored, such as entrainment of larval fishes at the export pumps. The problem of linking hydrodynamic and water quality models with ecosystem response was not discussed in detail at the workshop. Making this linkage, however, is essential if the Task Force is to address its full list of criteria. Experience has shown that the response of the Delta ecosystem to changes in conveyance is unpredictable and our recent leap forward in understanding ecological processes has not changed that. Although a dual conveyance system will likely reduce direct entrainment of fish at the south Delta pumping facilities, our models and understanding are not adequate to allow quantitative forecasts of the overall ecosystem response to changes in conveyance. Research is currently underway in the Bay-Delta and elsewhere to improve the linkages between hydrodynamics, water quality and ecosystem response. But reliable computer models of these relationships are not yet available for management purposes in the Bay-Delta. Thus, the available hydrodynamic models are of only limited usefulness in assessing the impacts of changing conveyance on ecosystem health and resilience.

None of the models discussed in the workshop provide any information on seismic and flood durability or project schedule, costs and funding. However, the output from these models is likely to be very important as input to any models that do address these criteria.

Although the panel advised caution in accepting the precise numbers that come from Delta models, it, nevertheless expressed the view that modeling provides useful information and insights into hydrodynamic, water quality and ecological responses to conveyance changes in the Delta. Indeed, for a complex engineered and natural system such as the Bay-Delta, computer-based modeling and simulation is virtually required. It is important, however, that the Task Force understand that the various types of models have greatly varying degrees of certainty associated with their predictions. The Task Force is advised to ask for estimates of uncertainty (the range of values within which predictions are most likely to fall) with any predictions from a quantitative model. The panel also cautioned that for each new application, models should be validated with field data. Furthermore, when it comes to linking hydrodynamic models with ecosystem responses, the reliability of the conceptual models upon which the predictions are based is often not known well enough to allow any estimate of the uncertainty in predicted outcomes. Great caution is advised when considering the results of any such models.

In addition, the panel offered the following comments on a variety of issues around modeling Delta hydrodynamics, water quality and some ecosystem related issues:

1. Dual conveyance modeling. Dual conveyance modeling can address questions about channel capacities given seasonal cross-Delta export demands and Delta tidal and net flow patterns that would affect the salinity field and pelagic fish transport. These questions are largely tractable with one-dimensional models like DSM2.

2. South Delta barriers modeling. The agricultural and fish barriers in the South Delta affect many issues of concern to the Task Force. The barriers present a challenge for modeling because the processes they affect require different kinds of models. For example, the barriers affect agricultural diversion water levels, the source (and thus quality) of water entrained by the water project pumps, and agricultural runoff contaminant transport. These issues are mostly tractable with one-dimensional models like DSM2. The barriers also affect San Joaquin River fish passage through the Delta, an issue that will require behavioral particle tracking and two-dimensional vertically averaged models, like RMA2, to account for fish transport and tidal cycle behavior. Dissolved oxygen in the Stockton Deep Water Ship Channel is seasonally depressed by nutrient inputs, low flows, and temperature stratification. Understanding processes that stratify the water column requires three-dimensional models.

3. Delta geometry change. The likelihood of catastrophic levee breaches from seismic or flood events poses questions about how such a large scale change in Delta geometry will affect a range of hydrodynamic and water quality parameters. Flooding of islands will change the tidal prism (or volume of water passing a given location during the tidal cycle), which can affect erosion and deposition patterns and instigate changes in the shape and alignment of Delta channels. Associated issues include changes in the salinity field, drinking water quality and ecosystem. The match between model capabilities and conceptual models of the processes underlying these changes is critical for producing policy relevant results.

4. Particle tracking models. Particle tracking models (PTMs) are receiving much more use as the models mature and our understanding of the response of fish and other organisms to tides and flow patterns improves. PTMs are being used in Individual Based Models of fish life history and to characterize water transport timescales including residence time, flushing time, and age. The expert panel is "hopeful" about these initiatives but raised concern about the uncertainty of model results. Careful sensitivity analysis will be required to foster confidence in results.

5. Sea-level rise. Sea-level rise presents one of the key challenges to a sustainable Vision of the Bay-Delta. Models are powerful tools for estimating how the land-water interface might change as sea-level rises. Modeling of sea-level rise to date has been hampered by the fact that model grids developed so far cover

only present sea level conditions. In essence, the model "grid" is the internal map upon which calculations of water elevation and currents are estimated. As sea-level rises, the location of the land water interface will change along the entire margin of the estuary from South Bay to the Delta and upstream beyond Sacramento. Accurate simulation of tidal propagation, flood stage, degree of inundation, etc requires that the grid include all parts of the estuary that have tidal influence.

Sea-level rise highlights an additional limitation of the models discussed. The salinity gradient along the axis of the estuary generates its own current patterns as fresh water is constantly trying to flow over the top of saltier ocean water. This phenomenon is known as "gravitational circulation" and it increases with water depth. Therefore, sea-level rise will expand the power of this mechanism. In general, simulation of gravitational circulation requires either a three-dimensional model or a careful parameterization of salinity mixing caused by gravitational circulation for one and two dimensional models. Existing models do not, as yet, deal well with gravitational circulation.

The panel was aware of two modeling groups that have simulated the consequences of sea level rise on salinity. These preliminary studies used model grids that are likely to be inadequate for accurate predictions. Gravitational circulation was also not included in either study. Study authors have been clear about these limitations in their analyses. Nevertheless, their results have been shared publicly. In the future, the modeling panel believes that researchers attempting sea-level rise modeling should first expand their model grid based on the best available land elevation data to encompass all the area expected to be inundated before additional sea-level rise modeling is offered. Second, since three-dimensional models will not likely be used directly for sea-level rise analysis, researchers modeling sea-level rise should either include a gravitational circulation parameterization or be very clear when reporting results that one was not used.

Table 1. Strengths and weaknesses of the delta hydrodynamic models discussed in the workshop.

Strengths	Weaknesses
DSM2: ➢ A fast and efficient model for multi-year simulations ➢ Code is in the public domain, limitations are known and comments from third parties have been included in the model development. ➢ Code based on numerical solution techniques that are well-known and tested. ➢ Deals with all the complexities of Delta hydrodynamics (e.g., barriers, gates, Delta island consumptive use, etc.) ➢ Support and training for the model is available from the Delta Modeling Section at DWR ➢ Well documented in a series of reports published annually by DWR ➢ The modeling system includes a unique, quasi-3D particle tracking code that has proven especially useful for ecological modeling applications.	➢ Limited by 1D approximations in large open water bodies and at complex channel junctions ➢ Neglects any effects from density gradients or wind on Delta hydrodynamics ➢ Uses a challenging location at Martinez for the specification of seaward boundary conditions for the model ➢ Does not include the lower San Francisco Bay ➢ Specifies only daily variations in pumping at the SWP ➢ Specifies only daily data for the model boundary condition on the Sacramento River that is tidally affected at low flows ➢ The Particle Tracking Model (PTM) may not fully capture dispersive mixing properties within complex channels or where large tidal variations occur ➢ The code for the PTM has proven difficult for others to modify and compile
RMA2: ➢ Allows for 2D computations in the Suisun Bay and the western Delta (but uses a 1D structure in Delta channels) ➢ Code released upon request to Resource Management Associates ➢ Code based on numerical solution techniques that are well-established and have been used in many model applications around the United States ➢ Support for the model and pre- and post-processing software are available from the RMA consulting firm or Boss International Corporation ➢ Deals with all the complexities of Delta hydrodynamics (e.g., barriers, gates, Delta island consumptive use, etc.) ➢ Represents the circulation and mixing in large open-water bodies better than DSM2	➢ The 2D calculations are done using a fully implicit numerical approach that is computer-intensive (even by 2D standards) and requires much more computer time for execution in the Delta than a 1D model ➢ For Delta-only simulations the model uses a challenging location at Martinez for the specification of seaward boundary conditions ➢ The 1D component of the model used for representing Delta channels is limited to trapezoidal-shaped cross-sections ➢ Support for the model and pre- and post-processing software are not free. ➢ Specifies only daily variations in pumping at the SWP ➢ Specifies only daily data for the model boundary condition on the Sacramento River that is tidally affected at low flows

Strengths	Weaknesses
➢ Uses an unstructured grid, which allows for extra grid points to be applied in areas of special interest ➢ Allows for representation of irregular boundary configurations ➢ Two-dimensional elements are allowed to wet and dry during a simulation ➢ A 2D and 1D particle-tracking code is available ➢ Coupled simulation of the hydrodynamic and density fields is possible. (The panel does not believe, however, that density gradient forcing has been included in most of the recent applications.) ➢ Two versions of the model (one including the lower portion of the Bay and one without it) are available	
UnTRIM: ➢ Allows for full 3D computations in the San Francisco Bay and the western Delta where density-gradient effects and lateral circulations are important ➢ Very efficient calculations for a 3D model ➢ Code based on semi-implicit, numerical solution techniques that are well-described in the published literature and have been applied to a variety of different applications. ➢ Support for the model is available from local consultants and at workshops held annually in Italy. Some pre- and post-processing software is available for purchase. ➢ Because of 3D capabilities, the model represents the circulation and mixing in large open-water bodies better than 1D and 2D models ➢ Uses an unstructured grid, which allows for extra grid points to be applied in areas of special interest ➢ Because of its unstructured grid the model allows for good representation of curved shorelines ➢ Grid cells are allowed to wet and dry during a simulation ➢ It is the best model for inclusion of density	➢ The model is proprietary and a license for its use must be purchased from the developer. Access to the full computer code is not allowed. ➢ Although most of the model principles are in the peer reviewed literature, there are elements of the model that are not fully described. ➢ Although the 3D calculations are very fast (by 3D model standards) the model still requires an enormous amount of computer time to run. It is unknown whether the model will be practical for full Bay and Delta simulations ➢ There is not yet a Delta version of the model available. When one is available, it will need to be calibrated. ➢ Does not deal with all the complexities of Delta hydrodynamics ➢ Formal training on the model is not available but could be arranged upon request ➢ A 3D particle tracking model is available, but it is brand new and still undergoing some development. ➢ UnTRIM has no true 1D model component that can be used for representing narrow Delta channels like the RMA2 model.

Strengths	Weaknesses
gradient effects on hydrodynamics. ➢ A square grid version of the model is available if desired.	➢ Support for the model and for pre- and post-processing software are not free ➢ Handles calculations for flow through entrance gates to Clifton Court Forebay somewhat crudely.