Testimony on
Water Balance Modeling
For the Comprehensive Review
And Update to the Bay - Delta Plan

Submitted by
Chris Shutes
FERC Projects Director
California Sportfishing Protection Alliance

and also submitted on behalf of
California Water Impact Network
And AquAlliance

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Water Balance Modeling for the Comprehensive Review And Update to the Bay - Delta Plan

Introduction: Multiple models, technical problems.

There is no single existing water balance modeling tool that is adequate to model the water balance impacts of potential measures that the State Water Resources Control Board will adopt in the update of the Water Quality Control Plan (Phases I and II), and any water rights conditions that may be required (Phases III and IV) pursuant to the standards adopted in Phases I and II. There are many available tools. The Board will need to use multiple tools. The diversity of tools, the diversity of people who know how to operate them and interpret their output, and the lack of familiarity with these diverse tools and persons on the part of Board members, Board staff, and stakeholders, create a series of difficult technical problems that the Board will need to confront.

CalSim II is the only widely used water balance and operations model that has the geographic coverage of most of the Sacramento – San Joaquin system. However CalSim II works on a monthly time step that is too coarse to understand the operations or the impacts of proposed changes to reservoir operations to meet the requirements of the update of the Water Quality Control Plan. The Board will need to modify or add to CalSim II in order to use this monthly time step model to understand the impacts of daily changes in operations, and in order to analyze the operational opportunities and impacts; the Board may even need to replace CalSim II altogether. The Board will also need to use models that have a daily time step to understand how rim dam operations in particular can be modified to help meet the needs for increased Delta outflow. Many such models have been developed in FERC relicensing proceedings, including models for the Yuba River Development Project (Yuba River), the Don Pedro Project (Tuolumne River), and the Merced River Project (Merced River).

Additional technical problems in the application of water balance models will include choosing the model or models appropriate to address each part of the overall issues, defining what potential modeling assumptions are available, selecting the modeling assumptions, and memorializing the assumptions and associated outcomes. Once these initial problems are solved, follow-up problems will include creating effective interface between models, and determining the governing variable or combination of variables in each outcome.

In addition to strictly technical problems, legal uncertainty creates further technical problems. Broadly speaking, the legal uncertainty revolves around how the Board will allocate responsibility for meeting any additional Delta flow requirements pursuant to the standards set in Phases I and II. This will include options for addressing flow requirements within watersheds and between watersheds; how the priority system will be enforced, and whether (or how) it will be modified; and how existing agreements and commitments (for instance, upper watershed lake level requirements) will be affected and perhaps modified. The technical problems that arise from legal uncertainty can be grouped into three basic categories: 1) which tools are appropriate to use; 2) how various tools will interface with each other; and 3) what assumptions the Board will model to capture various potential legal decisions or options.

Policy uncertainty creates still further technical problems. Examples of broad policy decisions that may affect selection of water balance models and modeling assumptions include decisions relating to cold water pools (especially in rim dams), hydropower, and upper watershed and foothill water supply. Some of these policy decisions may also be (arguably) legal requirements. Regardless, modeling assumptions that capture policy alternatives are similar to the technical problems that arise to capture those based on potential legal decisions or options.

The Board must use water balance models to analyze the impacts of alternatives for updates to the Water Quality Control Plan.

The Board must use water balance models to analyze the operational ability to meet requirements (existing ability, potential future infrastructure improvements), and in order to fully evaluate the impacts, of various alternatives. In particular, the Board must evaluate the water costs involved with prospective operational requirements. It must also analyze the instream effects of increased outflow in February through June.[1]

The Water Supply Effects (WSE) spreadsheet analysis done in the Feb 28, 2012 Phase I technical report (scientific basis) was therefore only a beginning.[2] The WSE "model" is not an operations model as such, but rather is a mass balance calculator of monthly amounts of inflow to San Joaquin tributary major storage dams (New Exchequer Dam, New Don Pedro Dam, New Melones Dam), and of the amounts of water that would be needed to meet percentage of outflow requirements from those three dams. The impacts are assumed to be the quantities of water lost for diversion based on a stated percentage of required instream flow.

The daily time-step water balance models developed for the Merced River Project and Don Pedro FERC relicensings would provide a much better picture of how operators on those rivers would (or could) actually operate their projects to meet outflow requirements. These models would also link up to water temperature models to evaluate instream and reservoir water temperatures, and to evaluate cold water pools.

The San Joaquin Tributary Association (SJTA) correctly pointed out that the WSE analysis in that technical report did not account for the power loss stemming from the head differential resulting from lower reservoir levels when it quantified the impacts on hydropower of various percent-of-unimpaired flow scenarios through the storage reservoirs on the Stanislaus, Tuolumne and Merced rivers.[3] A suite of more costly impacts will arise from operating reservoirs to comply with new flow requirements, including changes in timing of power production, buffers needed to assure compliance with flows, early season storage of water to manage reliability of later season deliveries, and loss of surface water for irrigation due to carryover storage requirements over and above diversion reductions stemming from water

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[1] See for example the analysis by Stephen Grinnell for Yuba County Water Agency submitted with YCWA's scoping comments for Phase II, April 25, 2012, which captures many of the operational and instream impacts of increasing spring outflow in the Yuba River, based on the water balance model developed for the relicensing of the Yuba River Development Project.

[2] SWRCB, *Technical Report On The Scientific Basis For Alternative San Joaquin River Flow And Southern Delta Salinity Objectives*, February 2012, Chapter 5.

[3] See letter of Tim O'Laughlin to SWRCB, "unsolicited comment" re "Hydropower Energy Analysis," May 24, 2012.

limitations within any single water year.[4] In addition, the impacts on instream temperatures and cold water pool needs are not captured with the technical report's spreadsheet analysis.

The Board must systematically model a wide range of flow scenarios and variables.

In updating the Water Quality Control Plan, the Board is dealing with cumulative effects that do not have easy answers. Every diverter claims that it must not mitigate someone else's effects. SJTA insists that diverters upstream of rim dams must contribute water to improve Delta water quality and other beneficial uses. Mountain counties insist that upstream diverters must not mitigate downstream effects of cumulative diversions. Every entity wants to mitigate only the direct effects of its own diversions. By definition, mitigating only direct effects will not mitigate cumulative effects on fisheries and other instream beneficial uses. These effects can simply no longer be ignored.

In order to evaluate the impacts of potential actions without being pre-decisional, the Board's Substitute Environmental Document will need to evaluate a large suite of alternatives. The Board's exercise of its authorities must not be limited by the fact that only selected actions were analyzed. The SED will need to analyze reasonable alternatives even if they are unpopular.

Many entities will not want to model scenarios that they argue would be illegal, or simply that would be undesirable. This is a paradigm that has become increasingly prevalent in FERC licensing processes over the last seven years: entities seek to suppress information or analysis because these entities perceive that suppressing analysis will reduce their exposure to undesirable outcomes. In these cases, entities make legal or policy arguments to suppress investigation, including potential modeling scenarios. In Investigation Order WR 2011-0003-EXEC, the Board resisted such an approach by Merced Irrigation District by ordering studies not ordered by FERC. Similarly, the Board must resist limitation of relevant information in the update of the Water Quality Control Plan (phases I and II). Every alternative that the Board analyzes will have opponents, because there is not enough water in the Sacramento – San Joaquin watershed to meet all the needs of people who want to use it.

In order to carry out its reasonable use and public interest mandates and to balance the public trust, the Board needs to understand the technical consequences of various alternative Phase III and Phase IV scenarios for allocation of responsibility for meeting standards developed in phases I and II. Technically this translates in part into understanding the impacts of different modeling assumptions. The modeling assumptions are much less challenging than the legal and policy issues that might be involved in implementing them.[5] As a technical exercise, the Board

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[4] Strict carryover storage requirements will almost certainly be required to protect beneficial uses. See letter of Audrey Kelm to SWRCB, "unsolicited comment" re "Modeling," May 3, 2012, p. 1:

> Also, while it is unclear how the State Water Board will model the Tuolumne River, Modesto Irrigation District and Turlock Irrigation District intend to divert and fully deliver to their landowners. As shown in the example described in our letter to you of April 30, 2012, this will draw New Don Pedro Reservoir lower than the State Water Board staff's initial analysis. The same is true at New Exchequer Reservoir.

[5] As examples, we cite two important but partially conflicting precedents:

must evaluate the technical issues now, because technically, the modeling results will vary radically depending on the assumptions upon which each simulation is based.

The Board can analyze a wide range of alternatives by surgically and transparently using water balance models to consider a wide range of modeling assumptions and scenarios. The question is not whether legal and policy assumptions will be made in modeling. They will. The question is whether modeling assumptions will be made explicitly, transparently, and systematically. They must.

The Board needs to construct a matrix or matrices with a series of variables for modeling assumptions. Some of the most obvious variables include:

- What percent of unimpaired flow should be required as Delta outflow in specified months?
- If x percent of unimpaired flow is required for Delta outflow, what percent of unimpaired flow must be passed through each rim dam in order to meet x percent Delta outflow (accounting for unregulated accretion)? How does this vary day by day, week by week, month by month, and storm by storm? Should there be an initial storage threshold above which the pass-through increases?
- Should dams upstream of rim dams be required to pass through a percentage of unimpaired inflow in order to contribute water that is passed through rim dams downstream? What percent? Does the required percent of pass-through from upper dams vary according to size? To need or use in the upper watershed? To water that is exported from the watershed today? To potential county of origin claims that may come in the future? How does this vary day by day, week by

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In Decision 1486, the Board stated on pp. 24-25:

> Although there was no specific legal obligation on the State Water Rights Board to protect the watershed of origin, there was the general authority of the Board to condition the decision in such a manner that the public interest be protected and that the Board exercised that authority in formulating Condition 11. The "first in time, first in right" rule contained in Water Code Sections 1450 and 1455 must be read together with Water Code Sections 1253 (authority to impose public interest conditions), 1255 (authority to reject applications not in the public interest), 1256 (duty to consider California Water Plan in determining the public interest), and 1257 (duty to consider the relative benefit to be derived from all beneficial uses of water). If the State Water Rights Board had read or if this Board were now to read Water Code Sections 1450 and 1455 myopically, without considering other applicable provisions of law, as the Bureau and CCRB request, a skewed administration of water rights in this state would result.

However, in the just released (2012) Light decision (SC-UK-CV-G-11-0059127-000 – LIGHT, RUDOLPH VS. CALIF STATE WATER RESOURCES), the Court stated on p. 30:

> The importance of the rule of priority is most apparent when the natural or abandoned flows in the watercourse are not sufficient to supply all demands. During periods of shortage, principles of water policy often collide. When the doctrines of reasonable use or public trust clash with the rule of priority, the rule of priority must yield. (*El Dorado* 142 Call App. 4th at 964, 966.) However, "*every effort*" must still be made to preserve water rights priorities. (*Ibid.*) (emphasis added.)

week, month by month, and storm by storm? Should there be an initial storage threshold above which the pass-through increases?

- Should storage in rim dams and upper watersheds be preferentially treated in relation to direct diversions for export in the Delta? If so, how should this preference be quantified?
- Should certain rim dams be preferentially treated over other rim dams because of the public interest in its particular storage benefits, or because anadromous fish are present or not present in rivers immediately downstream?
- What carryover storage requirements should be required for each rim dam?
- How will rule curves be written for pass-through of unimpaired flow and for carryover storage?
- How will operators game the rules in ways that reduce the benefits to instream beneficial uses? How can rules be written to avoid gaming and best preserve the instream benefits?

Board modelers must dig into the rules that govern each model; they must evaluate and where necessary modify the rules and particularly the sequences established in the models according to which different demands are met.

Water balance models are set up with a series of rules that in many respects are similar to a series of priorities that are established in a water rights system. In fact, the projects' interpretation of the priority system for many major Central Valley water rights is embedded in CalSim II, and CalSim II is the vehicle through which many aspects of Central Valley priorities (particularly those pursuant to the CVP and SWP) are administered. Within CalSim II's operating rules, there are additional priorities for non-diversion requirements, such as instream flows at different point, carryover storage (generally as soft targets), water temperature requirements, salinity requirements, and so forth. However, these non-diversion priorities are set up in the model as constraints, and once these constraints are met, the purpose of CalSim II is to optimize project diversions.

Since the Board needs to examine the priorities within CalSim II and perhaps modify them, the Board's modelers cannot simply "run the model" and crank out the results. This would result in a skewed outcome. The modelers must evaluate the rules and priorities within CalSim II even as they seek to set up modeling scenarios. They must modify existing rules and also potentially add rules to cover or add detail to Delta inputs that are not explicitly addressed in CalSim II today.[6]

If assumptions that are hard-wired (or close to hard-wired) in CalSim II are not systematically evaluated and modified as appropriate, then the modeling outcomes will be irreparably biased. Suppose, for example, that a BDCP alternative were analyzed in CalSim II that guaranteed existing or greater levels of exports, but also left priorities in place that guaranteed that north of Delta CVP and SWP contractors got their existing water allocations before export levels were met. Suppose also that other non-project area of origin Sacramento

[6] Inflow from Putah Creek, for example, is not disaggregated in CalSim II from unregulated Delta inflow, even though maximum storage in Lake Berryessa is 1.6 Million acre-feet.

watershed diverters got their diversions as diverters senior to exports, except under Term 91conditions. Delta outflow increases would then largely be left as the responsibility of Eastside San Joaquin and Mokelumne/Calaveras diverters. If one were to factor in the priority dates of the water rights on the Eastside San Joaquin and Mokelumne/Calaveras rivers, one could likely prove that it would "impossible" to substantially increase Delta outflow.

Some rules in upstream water balance models will likely also need to be changed. However, this should be less difficult and complex than changes to operating rules in CalSim II.

The Board needs independent modeling capacity. Board modelers must either be able to re-work the rules and priorities of existing water balance models to use for Board purposes, or create an entirely new model that allows inputs whose goal is to optimize environmental benefits.

In order to effectively and expansively use and available water balance modeling tools, the Board needs its own independent modeling capacity.[7] The Board, Board staff, and modelers must work interactively and iteratively. Modelers will inevitably come up with questions and issues that Staff does not consider on its own. In addition, the modelers will need to help Board Staff to understand the models and their capability, likely to a greater degree than Staff will need to educate the modelers on potential legal and policy issues that need to be reflected in modeling.

Because, as noted above, it will be necessary to go into CalSim II and other models and iteratively modify the rules and priorities within the models, it will not be sufficient for the Board to simply compare model runs performed by interested parties and choose among those, like choosing different models of automobiles. The car analogy would not be reinventing the wheel, but it might be designing a whole new product line.

It is possible that the operating rules of CalSim II are so restrictive and cumbersome that Board modelers cannot deconstruct and reconstruct it to be the adequate technical representation of the implementation of the Board's policy and legal options and choices. In such case, the Board would need to create its own model of the Sacramento – San Joaquin hydrologic system. This would require a second group of modelers to construct a new model in time for Phases III and IV of the update of the Water Quality Control Plan, even as the first modelers make the best they can out of existing models during Phases I and II. If the Board creates a new system-wide water balance model, it should be a public domain model with both daily and monthly time step options (including a daily time-step options for parts of the model) that provides multiple input and output features, including features that allow the user to make changes in operating rules with the goal of optimizing environmental benefits.

As the Board's modelers complete their work, the Board will need to convene a series of modeling workshops to introduce modifications to existing water balance tools or to introduce new tools, to show its work, and to carry out a step-by-step review and analysis of the Board's modeling. The workshops must review model calibration and validation, and must provide training for model use.

[7] We offer no opinion on whether this capacity is in-house or outside consultant or both. However, it cannot be absentee capacity: modelers working for the Board must work closely and frequently with the Board and staff.

Additionally, the Board will need to provide an extensive modeling appendix in each SED that is both technically thorough and also stated in a language that is accessible to interested parties who are not modelers.

The Board must catalogue water balance modeling tools, define their appropriate use, define gaps, and begin needed additions, modifications, or replacements.

Below we list major water balance models that we know of that may be of use to the Board in the update of the Water Quality Control Plan. We also note and comment on selected qualities of these models. This is not intended to be a complete inventory of existing water balance models that model hydroelectric or water supply developments in the Sacramento – San Joaquin system.

I. Water balance models whose geographic scope includes the Sacramento – San Joaquin system (but lack individual nodes for many key watersheds)

Model	Time step	Public domain?	Assumptions and rules transparent?	Can be run by many engineers?	Rules can be modified by many engineers?	Reviewed in development by multiple stakeholders?	Hard-Wired Rules?
CalSimII	Monthly	No	No	No	No	No	Yes
CalLite	Monthly	Yes	No	Yes	No	No	Yes
WEAP	Weekly	No	No	No	No	No	?

Comments:

1. CalSim II has become the default model when the State Board considers broad water issues in the Sacramento – San Joaquin watershed, first of all because CalSim II encompasses a geographic scope that no other water balance model encompasses. It is essential to remember that CalSim II is designed for operators to operate the Central Valley Project and the State Water Project, generally in the context of existing regulatory requirements as recently interpreted. CalSim II views these requirements as constraints, and then seeks to optimize deliveries to contractors. When the Board considers substantially modifying flow requirements, constraints will begin to compete within the model, and the model will try to do the balancing that the Board should do. The solution is for the Board to define priorities, and for engineers to consciously modify priorities within the model. Complicating the problem is the monthly time step of CalSim II, which does not allow close examination of operations within a month. So the same engineers need to add features to CalSim II, likely as external time series or smaller models, to drill down into actual operations. Finally, the engineers will need to set up an interface between CalSim II and daily models for rim dams where these models are available, changing the flow inputs to CalSim II from reservoir nodes such as New Bullards and New Exchequer by using output from the rim dam models as inputs to CalSim II.

2. CalLite is a simplified version of CalSim II that has been used in BDCP planning to gain rough evaluations of water costs of different scenarios. Using a simplified model such as this for Water Quality Control Plan analysis would be completely inappropriate. Accessibility should not be achieved by approximating or dumbing down CalSim II. This will not only provide access to an inferior tool, it will further bury the underlying assumptions and rules that must be modified by knowledgeable engineers to make the tool serve the purpose.

3. We do not recommend the WEAP (Water Evaluation and Planning (WEAP) model. So far as I know, a Sacramento – San Joaquin WEAP model is not built. Of the two WEAP models of upper watersheds in California that I have seen, they did not adequately calibrate. WEAP is somewhat useful as a comparative tool to evaluate climate change scenarios because it does not rely on past hydrology. However, this conceptual benefit is the model's practical downfall: the method of developing the hydrology is not sufficiently accurate.

II. Water balance models whose geographic scope includes Sacramento – San Joaquin rim dams and major tributaries downstream

Model	Time step	Public domain ?	Assumptions and rules transparent?	Can be run by many engineers?	Rules can be modified by many engineers?	Reviewed in development by multiple stakeholders?	Hard-Wired Rules ?
Merced Project (Excel)	Daily	Yes	Yes	Yes	Potentially	Yes	Yes
Yuba River Project (Excel)	Daily	Yes	Yes	Yes	Potentially	Yes	No
Don Pedro Project (Excel)	Daily	Yes	Yes	Yes	No	Some review	Yes
Oroville (Hydrops)	Weekly	No	No	No	No	Yes	Yes
MOCASIM (?)	?	No	No	No	No	No	?
Folsom Ops (Modified CalSimII)	?	No	No	No	No	No	?
New Melones (Excel)	Monthly	No	?	?	?	No	?

Comments:

1. Hydrology development and model calibration for the Excel model for Yuba River Development Project was reviewed extensively by relicensing participants, agency engineers in particular.

2. Hydrology development and model calibration for the Excel model for Merced River Project was reviewed by relicensing participants, agency engineers in particular. The model was changed following suggestions from relicensing participants.

3. Hydrology development and model calibration for the Excel model for Don Pedro Project is currently undergoing review by relicensing participants. Agency engineers have expressed concerns about use of reservoir gage data to establish daily inflow to reservoirs; this method creates negative flow numbers in river nodes upstream of Don Pedro. It is likely that upstream hydrology issues with this model will not limit its usefulness for Water Quality Control Plan purposes. The Don Pedro model includes diversions to the City and County of San Francisco from the Hetch Hetchy system.

4. Oroville Hydrops model is a hydropower optimization model that looks only at operations within the Oroville facilities. It must be linked with CalSim II; CalSim II defines the demand from Oroville for State Water Project timing, deliveries, and carryover storage. Oroville thus does not have a self-contained operations model comparable to the models for Yuba River Development, Merced, or Don Pedro.

5. MOCASIM is a proprietary model used by San Joaquin County for water rights planning on the Mokelumne River. So far as we know, it has never been made available to resource agencies or other interested parties.

6. Placer County Water Agency is modifying CalSim II so that PCWA can less coarsely simulate Folsom Reservoir operations in the context of petitions for extension of time on PCWA's American River water rights. This is one potential approach that the Board might consider for major reservoirs for which daily operations models do not exist.

7. The San Joaquin Tributaries Association has developed a monthly Excel based model for the Stanislaus and for the Tuolumne, Merced, and lower San Joaquin rivers. The daily models developed for the Don Pedro and Merced relicensings are more detailed and more useful in considering potential operations than the monthly model. SJTA may have, or may be able to develop, a daily Excel model for the Stanislaus.

III. Water balance models whose geographic scope includes hydroelectric and water supply developments upstream of major Sacramento – San Joaquin rim dams

Model	Time step	Public domain?	Assumptions and rules transparent?	Can be run by many engineers?	Rules can be modified by many engineers?	Reviewed in development by multiple stakeholders?	Hard-Wired Rules?
Yuba-Bear/ Drum-Spaulding (HEC ResSim)	Daily	Yes	Yes	Yes	Yes	Yes	No
Middle Fork American River Project (OASIS)	Daily	No	Yes	No	No	Yes	No
El Dorado Project (OASIS)	Daily	No	Yes	No	No	Yes	No
Upper American River Project (HEC ResSim)	Daily	Yes	Yes	Yes	Yes	Yes	No

Comments:

1. Hydrology development and model calibration for the Excel model for Yuba River Development Project was reviewed extensively by relicensing participants, agency engineers in particular. It was further reviewed by agency and licensee-consultant modelers during use over two years. The output from this model is already incorporated as input to the Excel model for the Yuba River Development Project.
2. OASIS model is proprietary, but the linear solver was provided by Placer County Water Agency (PCWA) to resource agency modelers for use in the Middle Fork American Project relicensing.
3. Hydrology development for El Dorado Project was thoroughly reported to and reviewed by relicensing participants. OASIS model is proprietary, but the linear solver was purchased by Forest Service for use by agency modelers in the El Dorado relicensing.
4. HEC ResSim model for the Upper American River Project (UARP) was constructed by modelers for the Forest Service and the California Department of Fish and Game. The

CHEOPS model developed by licensee Sacramento Municipal Utilities District was cumbersome for scenario development and not made readily available to relicensing participants. The HEC ResSim model was used by El Dorado County in its EIR to support Applications 5644 and 5645 to appropriate water stored in UARP reservoirs.

5. As I understand it, PCWA will use output from models for the Middle Fork American, El Dorado, and UARP projects as input to its modeling to support proposed operational changes to Folsom Reservoir in the context of its petition to extend time for PCWA's American River water rights. This type of interface should be used by the Board. The Board should more extensively use such upper watershed water balance models in evaluating impacts associated with scenarios that require upper watershed water purveyors to pass through water or release water from storage to meet Delta flow requirements.

Conclusion: 5 points the Board must remember about water balance models.

1. The State Water Board needs its own independent modelers. The Board and Board staff must work iteratively and interactively with these modelers to evaluate alternatives and impacts of scenarios for achieving the goals of the update of the Water Quality Control Plan.

2. There is no single existing water balance modeling tool that is adequate to model the water balance impacts of potential measures that the State Water Board will be adopted in the update of the Water Quality Control Plan (Phases I and II), and any water rights conditions that may be required (Phases III and IV) pursuant to the standards adopted in Phases I and II.

3. The Board needs a water balance model for the Sacramento – San Joaquin hydrologic system that is the servant of the Board's policies and interpretation of it authorities and legal mandates.

4. Board modelers must modify the rules and priorities within CalSim II and, to a lesser degree, within water balance models that simulate rim dam and upper watershed reservoir operation. Use of existing models, particularly CalSim II, without such modification will mean that the tool defines the policy and the law. If the Board cannot make CalSim II serve its purposes, it must create a new water balance model for the Sacramento – San Joaquin system.

5. Modeling rules, assumptions, inputs and outputs for the update of the Water Quality Control Plan must be transparent and thoroughly disclosed.

Appendix

Chris Shutes: Experience with Water Balance Modeling 1999-2012

I began working on relicensing hydroelectric projects as an unaffiliated, volunteer stream fisheries advocate in 1999. The first project I worked on was the El Dorado Project operated by El Dorado Irrigation District (EID). The storage reservoirs in this project (Silver, Caples and Aloha lakes) had also been the focus of water rights controversy and litigation. The synthesized hydrology dataset and OASIS water balance model developed for the project by consultant Hydrologics (later, part of ECORP) became the key to a successful outcome. EID and stakeholders used the model extensively and transparently to develop and evaluate flow and storage scenarios. During this process, I became proficient at proposing model scenarios and interpreting model output. I also became intimately familiar with project hydrology. Using these tools and Excel, I developed a lake level proposal for Silver Lake that became the basis for resolving 10 years of litigation.

In 2003, I became involved in the relicensing of the Upper American River Project, operated by the Sacramento Municipal Utilities District (SMUD). SMUD's CHEOPS water balance model was not well suited to scenario development. Access to the model and scenario development was also restricted by SMUD. Consequently, a hydrologist from the Forest Service and an engineer from the Department of Fish and Game constructed their own HEC ResSim water balance model of the project. This model became the default model for the process, and enabled accessible scenario development. Because this model was built on a public domain platform, it subsequently was available for use by others.

Since the California Sportfishing Protection Alliance hired me in 2006 to work on hydroelectric project relicensings and implementations, I have worked with multiple additional water balance models.

- I became extremely familiar in 2007-2009 with the hydrology of the DeSabla – Centerville Project on Butte Creek and the West Branch Feather River, and the HEC ResSim model that PG&E developed for relicensing this project. I insisted on modeling scenarios that were not desired by the project operator. I assisted a modeler from the Stockholm Environmental Institute to understand project hydrology and operation so that she could develop a WEAP-based model of the same system in order to evaluate potential impacts to Butte Creek under climate change.
- In the relicensing of the Middle Fork American Project, licensee Placer County Water Agency (PCWA) extensively used an OASIS model. As was the case in EID's relicensing, PCWA put ECORP modelers at the disposal of relicensing stakeholders.
- In the coordinated relicensing of the Yuba-Bear Project, operated by Nevada Irrigation District (NID) and the Drum-Spaulding Project, operated by PG&E, HDR, consultants for the licensees, worked in dozens of meetings with agency and NGO participants to develop and verify the hydrology and to develop and make multiple improvements to the HEC ResSim water balance model. The

ability of agency modelers to independently run the model for these elaborate projects on the Middle Yuba, South Yuba and Bear rivers has been critical to progress. Agency and consultant modelers instructed me on how to make flow scenario inputs to the model, and how to use the model to view the actual water in the river at each accretion node for any day in the period of record.

- I (along with agency personnel) successfully advocated for expansion of the geographic scope of the Excel-based water balance model developed for the relicensing of the Merced River Project in 2009-2010. I attended several model presentations by consultants for licensee Merced Irrigation District, and advocated for several modifications. Together with agency modelers and biologists, I have proposed various exploratory flow scenarios in 2011 and 2012. With recently upgraded computer capacity, I am able to run this model.
- In the relicensing of the Yuba River Development Project, operated by Yuba County Water Agency, I have attended meetings in 2011 and 2012 to review development of project hydrology, and have attended meetings where the Excel-based water balance model was presented and discussed. I will also be able to run this model.
- In the relicensing of the Don Pedro Project, operated by Modesto Irrigation District and Turlock Irrigation District, I have attended workshops in 2012 where project hydrology was presented and discussed. I attended the roll-out of the Excel-based water balance model on October 23, 2012. I anticipate that there will be refinements and modifications required of the first iteration of the model.

In summary, in over ten years in multiple relicensings, I have become very familiar with multiple water balance models. I have seen widely diverse approaches to their use. I have seen models used transparently and openly, whether available for general use or proprietary. I have seen models constructed to avoid undesired analysis and outcomes, and I have seen them gamed to avoid undesired outcomes and to arrive at desired conclusions.

I presented testimony in the 2010 water rights hearings on Applications 30358 A and B of Davis and Woodland. In my oral testimony, I took the Board to task for failing to conduct independent technical analysis of water availability to support the applications. My purpose in recounting this is not to revisit the merits of those earlier applications, but to state once again that the Board needs its own independent water balance modeling expertise. The Board cannot simply be consumer or even referee of competing modeling presentations whose purpose is advocacy of a position, and where modeling assumptions and operating rules are not transparent.