california water impact network

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December 4, 2007

Delores Brown, Chief
Office of Environmental Compliance
Department of Water Resources

RE: Monterey Plus Amendments to the SWP Contracts Draft EIR

Dear Ms. Brown,

Thank you for this opportunity to express concerns regarding the proposed amendments to the SWP contracts.

The amendments changed the contracts in several fundamental ways, all of them bad for the environment, and bad for the state's ability to manage our water resources in the public interest. If (when) this new Draft EIR is formally approved by DWR, it would:

- Eliminate the requirement that agriculture take the first hit during times of drought before urban areas leaving urban areas vulnerable.

- Hand over the state-owned Kern Water Bank, the largest groundwater storage facility in California, to a coalition of interests dominated by private corporations, despite state laws that prohibit just such a transfer. This would effectively privatize a major storage facility and make the State Water Project less reliable.

- Eliminate the original contract requirement that DWR must determine the realistic yield of the SWP and limit contract deliveries to that amount. Instead, the proposed contract amendment would allow DWR to continue promising to deliver water that does not exist, "paper water," which has been used to fuel unwise development all over California.

- Allow DWR to continue over-pumping from the Delta in the winter and spring months, which has already, under the provisional use of the Monterey Amendments, contributed to the near extinction of the Delta smelt and other Bay-Delta fish populations.

- New transfer rules allow contractors to sell water outside their service areas; this begins the privatization of the State Water Project. The sum total of the amendments means a loss of accountability to the state.

- Changing the so called "surplus Article 21 water" to "interruptible water" is allowing water marketing where contractors and developers are counting on this non-

permanent water for building homes and business; not a sustainable practice. The amendments remove the clause that specifically states that permanent economics like new houses are not supposed to be founded on Article 21 surplus water.

C-WIN is preparing extensive comments on this Draft EIR to be submitted to DWR in mid-December, pointing out its many problems. However, given past experience, we have every reason to believe that our concerns will be largely ignored and that DWR will adopt a final EIR that is very close to the original.

At this time, I would incorporate the "Declaration of John Leahigh In Support of the California Department of Water Resources' Proposed Interim Remedy" August 21, 2007. Mr. Leahigh concludes that to meet the requirements of the State Water Resources Control Board Decision 1641 (D-1641), The SWP and the CVP would have to reduce pumping exports considerably (see attachment #1). Mr. Leahigh assumed that both the SWP and the CVP are equally responsible for meeting the objectives of D-1641. If this is taken literally, the SWP would have to reduce exports by 220-440 taf a year in dry years and by 825 tafy to 1.16 mafy in average years. This is very significant since the average actual deliveries of the SWP from 1990- 2004 was just 2.0 mafy.

I would also like to include in the record here my letter to DWR Director Lester Snow of May 31, 2007 (attachment #2.) This letter goes into great detail about the above stated concerns. Related to this letter is a press release that C-WIN put out in conjunction with this letter to Director Snow (attachment #3.)

C-WIN hereby incorporates all other comments opposing this Draft EIR in its present form.

Thank you so much for the opportunity to comment,

Respectfully submitted,

Carolee Krieger

Carolee Krieger, President

Attachments:

1. "Declaration of John Leahigh In Support of the California Department Of Water Resources Proposed Interim Remedy", August 21, 2007

2. C-WIN letter from Carolee Krieger to DWR Director Lester Snow, May 31, 2007

3. C-WIN Press Release for the Lester Snow letter

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attachment #1

IN THE UNITED STATES DISTRICT COURT

FOR THE EASTERN DISTRICT OF CALIFORNIA

NATURAL RESOURCES DEFENSE COUNCIL, et al., Plaintiffs, v. **DIRK KEMPTHORNE, in his official capacity as Secretary of the Interior, et al.,** Defendants, **SAN LUIS & DELTA-MENDOTA WATER AUTHORITY and WESTLANDS WATER DISTRICT; CALIFORNIA FARM BUREAU FEDERATION; GLENN-COLUSA IRRIGATION DISTRICT, et al.; CALIFORNIA DEPARTMENT OF WATER RESOURCES, and STATE WATER CONTRACTORS,** Defendant-Intervenors.	05 CV 01207 OWW (LJO) **DECLARATION OF JOHN LEAHIGH IN SUPPORT OF THE CALIFORNIA DEPARTMENT OF WATER RESOURCES' PROPOSED INTERIM REMEDY** Hearing: August 21, 2007 Time: 9:00 a.m. Courtroom: 3 Judge: Hon. Oliver W. Wanger

I, John Leahigh, declare as follows:

1. I am employed by the Department of Water Resources (DWR) as Chief of the Project Operations Planning Branch (POPB) within the Division of Operations and Maintenance. I have been in my current position since March 2005.

2. I am responsible for short-term planning of water operations for the State Water Project (SWP). These planning responsibilities include the estimation of delivery capabilities of the SWP and forecasted water export operations from the Sacramento/San Joaquin Delta (Delta) through the Harvey O. Banks Delta Pumping Plant (Banks), Skinner Fish Protection Facility (Skinner), and Clifton Court Forebay (CCF).

3. Prior to taking the position of Chief of the POPB, I worked within the branch in various engineering classifications from November 1996 through February 2005. I have worked for DWR since May 1992. I received a Bachelor's degree in Civil Engineering from the University of New Mexico in 1989 and a Master's degree in Civil Engineering with emphasis on Water Resources Engineering from California State University at Sacramento in 1999. I am a registered Civil Engineer in the State of California.

4. One of my responsibilities as Chief of the POPB is to supervise the work of engineering staff that develop and monitor studies, projections and delivery capabilities of the SWP. I coordinate with a team of engineers to plan and schedule water export operations based on water availability, water permit/quality restrictions, environmental needs, and projected hydrology.

5. I have personal knowledge of the facts stated herein, and, if called to do so, could and would testify competently thereto.

6. I am familiar with and contributed to the development of the proposed remedy actions, set forth in the Delta Smelt Action Matrix for Water Year 2008 (Action Matrix)[1], proposed by the United States Fish and Wildlife Service (USFWS), as supported by DWR. The Action Matrix has been developed to minimize and prevent adverse impacts to delta smelt and its habitat from SWP and CVP operations during the interim period pending completion of the consultation on the delta smelt with USFWS. I am informed and believe that the USFWS will complete the consultation and issue its biological opinion before August 2008.

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1. A copy of the Action Matrix is attached as Exhibit A to the Declaration of Jerry Johns in Support of the California Department of Water Resources' Proposed Interim Remedy, filed concurrently herewith.

7. I have worked with POPB staff to develop an estimate of the water costs associated with implementation of the Action Matrix through July 2008.

8. For the purposes of the following analysis, "water costs" are defined as the estimated export reductions and the estimated reductions in deliveries of water to CVP/SWP contractors for 2008 as a result of implementing the actions described in the Action Matrix.

9. The term baseline" is defined as the expected delivery of water without implementing the Actions proposed in the USFWS remedy matrix. Baseline water deliveries often vary depending on hydrology and the costs estimates are based on two different hydrology assumptions, as described in detail below.

10. Water supply forecasting requires a projection of initial reservoir storages and forecasted runoff as a foundation to delivery estimates. Reliable projections are available for the initial reservoir storages going into 2008, but the forecasted runoff is largely dependent on the amount of precipitation that will be experienced next year, which is unknown and could vary greatly. Water supply costs were analyzed for 2008 with two different assumptions on the amount of precipitation that may be experienced in 2008: dry and average.

11. A year with low precipitation or a "dry year" for the purposes of my analysis assumes the amount of precipitation in 2008 will be equal to the amount of precipitation that was exceeded 90% of the time over the past 85 years.

12. A year with average precipitation or an "average year" for the purposes of my analysis assumes the amount of precipitation in 2008 will be equal to the amount of precipitation that was exceeded 50% of the time over the past 85 years.

13. Although many different assumptions could be made for the amount of precipitation that could occur in any year, assumptions of precipitation at a 90% and 50% chance of exceedence are the most widely used water supply forecasting assumptions. These two hydrologic assumptions generally give a good analytical range for project operations.

EXISTING RESTRICTIONS ON WATER DELIVERIES

14. DWR provides water to twenty-nine (29) contractors throughout California under water right permits issued by the State Water Resources Control Board (SWRCB). These permits

include restrictions on water exports. The DWR permit most recently issued by the SWRCB resulted in a SWRCB decision, known as Water Rights Decision 1641 (D-1641). Details of the decision can be found at 14. DWR provides water to twenty-nine (29) contractors throughout California under water right permits issued by the State Water Resources Control Board (SWRCB). These permits include restrictions on water exports. The DWR permit most recently issued by the SWRCB resulted in a SWRCB decision, known as Water Rights Decision 1641 (D-1641). Details of the decision can be found at http://www.waterrights.ca.gov/baydelta/d1641.htm.

15. The water costs associated with the Action Matrix are measured against allowable deliveries under baseline operations, considering all flow and water quality objectives required by D-1641. Through D-1641, the SWRCB assigns responsibility for meeting water quality objectives adopted in the Water Quality Control Plan ("WQCP") for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary. These WQCP objectives protect fish and wildlife, and the agricultural, municipal and industrial uses of water.

16. The WQCP was updated in 2006. The new plan did not result in any changes in the requirements of D-1641. The new WQCP can be found at http://www.waterrights.ca.gov/baydelta/docs/rev2006wqcp.pdf.

17. A team of engineers and I took into account the restrictions imposed by meeting the objectives of the WQCP when developing the estimates for water costs associated with the implementation of the Action Matrix.

ASSUMPTIONS FOR THE IMPLEMENTATION OF ACTIONS

18. I assumed in the analysis that Action 1 would be triggered and implemented as of December 25, 2007 and continue through January 3, 2008. December 25 is described as the first possible day to trigger this 10-day Action in the Action Matrix.

19. I assumed in the analysis that delta smelt spawning will occur on February 20, 2008. February 20 is the date on which DWR biologists have estimated that spawning has begun historically. This assumption establishes the durations of Actions 2 and 3, which could vary significantly. The end of Action 2 and the trigger for the start of Action 3 is the onset spawning

as described in the Action Matrix.

20. In the Action Matrix, Actions 3 and 4 assume a range of flow objectives. A range of Old and Middle River upstream flows between 0 and 4000 cubic feet per second (cfs) is explicitly described and assumed for analyzing Action 3.

21. Action 4 does not have targeted flow but allows a range similar to Action 3 (from zero to approximately 4000 cfs).

22. Because the Action Matrix describes Actions 3 and 4 flow objectives as a range I assumed a range for water costs as well. The high end of this range assumes that the Old and Middle River objective is 0 cfs for both Actions 3 and 4. For determining the lower costs in the range I assumed that Action 3 is implemented at the 4000 cfs flow objective and Action 4 is not triggered, resulting is no water costs.

23. This range of cost was necessary as part of the analysis because of the uncertainty related to the real-time distribution of delta smelt and the susceptibility of this distribution to the exports as noted in footnotes of the Action Matrix.

ESTIMATED EXPORT REDUCTIONS ASSOCIATED WITH THE USFWS'S REMEDY PROPOSAL

24. Implementation of flow objectives in the Action Matrix will require reductions in export operations by the SWP and CVP. My team of engineers and I estimated ranges of export reductions associated with each Action in the Action Matrix. The ranges are based on 2008 being dry or having average precipitation as defined earlier. In addition, Actions 3 and 4 have sub-ranges due to their adaptive nature.

#1. reductions: 100 taf (dry yr.) 160 taf (average)

25. Action 1 - Winter Pulse Flow to Benefit Adult Spawning: CVP and SWP target upstream Old and Middle River flow not to exceed 2,000 cfs for a 10-day period during late December or early January. This action is estimated to reduce combined project exports by 100 thousand acre-feet (taf) in a dry year and 160 taf in an average year.

#2. 150 taf (dry yr.) 500 taf (average yr.)

26. Action 2 - Adult Salvage Minimized: CVP and SWP target upstream Old and Middle River flow not to exceed 4,500 cfs from early January to late February. This action is estimated to reduce combined project exports by 150 taf in a dry year and 500 taf in an average year.

reductions of: 440-880 taf (dry yr)

1.65 – 2.31 maf average yr. reductions

#3. reductions 60-500 taf (dry) (640 taf – 1.3 maf average)

#4. reductions 130 taf (dry) 350 taf (average)

total dry yr: 100 taf 150 taf 0-500 taf 10 taf 440 – 880 taf

average yr: ~~150 taf~~ 500 taf 640 taf – 1.3 maf 350 taf 1.65 – 2.31 maf

27. Action 3 – Larval and Juvenile Protection: CVP and SWP target upstream Old and Middle River flow between 4,000 cfs to 0 cfs from late February through the end of May. This action is estimated to reduce combined project exports by 60 taf to 500 taf in a dry year and 640 taf to 1.3 million-acre feet (maf) in an average year.

28. Action 4 – Juvenile Protection: If triggered, the CVP and SWP may target upstream Old and Middle River flow of up to 0 cfs in June. This action is estimated to reduce combined project exports up to 130 taf in a dry year and up to 350 taf in an average year.

29. Action 5 - Barrier Operations: There were no additional export reductions associated with this action.

COMBINED SWP/CVP ESTIMATED DELIVERY REDUCTIONS

30. I assumed in my analysis that both the SWP and CVP are equally responsible for meeting the objectives in the Action Matrix. The estimated delivery reductions provided below represent combined CVP/SWP delivery reductions.

31. Export reductions do not result in a one-for-one impact on deliveries because of a multitude of complicating factors including system constraints, runoff patterns, annual delivery patterns, and operational flexibility.

32. The export reductions for each action were entered into an operational spreadsheet model developed by DWR staff that estimates the delivery capabilities of the SWP and CVP. We modeled the remedy period with the implementation of the Action Matrix and without implementation of the Action Matrix. A comparison of model output indicates what annual delivery reduction could occur in 2008 if all proposed actions are implemented.

33. The resulting delivery reductions are expressed as a range for each hydrologic assumption for the same reason that the export reductions were expressed as a range. Actions 3 and 4 of the Action Matrix have an adaptive management process that will vary the flow objective.

34. The conclusion of the analysis is that the sum of all these export reductions in a dry year is expected to decrease combined 2008 deliveries of the SWP and CVP by 6% (183 taf) to 25% (814 taf) from a baseline delivery of 3.2 maf.

35. In an average year, the delivery reductions are expected to be between 14% (820 taf) to 37% (2.17 maf) from a baseline delivery of 5.9 maf.

SWP SHARE OF ESTIMATED DELIVERY REDUCTIONS

36. The analysis showed that the SWP 2008 annual deliveries would be reduced 8% (91 taf) to 27% (305 taf) from a baseline delivery of 1.15 maf in a dry year.

37. In an average year, SWP 2008 annual deliveries would be reduced 8% (252 taf) to 31% (940 taf) from a baseline delivery of 3 maf.

I declare under penalty of perjury under the laws of the State of California that the foregoing is true and correct.

Executed this 9th day of July, 2007 at Sacramento, California

JOHN LEAHIGH, Declarant.

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Attachment #2

california water impact network

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May 31, 2007

Lester Snow, Director
Department of Water Resources
P.O. Box 942836, Rm. 1115-1
Sacramento, CA 94236

Dear Mr. Snow,

I am writing to recommend a reduction in State Water Project (SWP) Table A Allocations from 4.1 million acre feet a year (MAFY) to a level that ensures the average annual delivery does not exceed 1.17 MAFY. This letter will explain why this is necessary and how we arrived at this figure.

On March 22, 2007, Alameda Superior Court Judge Frank Roesch ordered the State Department of Water Resources (DWR) to shut down its Harvey O. Banks Pumping Plant, the major facility that pumps water to Southern California, in 60 days unless DWR obtains a long-required permit to kill endangered fish. *Watershed Enforcers v. Dept. of Water Resources*, Case No. RG06292124. On April 18, 2007, Judge Roesch affirmed his earlier order and started the 60 day clock. Regardless of the outcome of DWR's pending appeal from this decision, the case provides DWR a unique opportunity to capitalize on the current political will to tackle the growing crisis in the San Francisco-San Joaquin Delta.

The California Water Impact Network (C-WIN) is a statewide organization dedicated to promoting equitable and environmentally sensitive uses of California's water. We would like to suggest a solution to the crisis in the Delta that may help satisfy Judge Roesch, thereby avoiding a complete shutdown of the Banks pumps, while also addressing other long-neglected issues.

The ultimate question raised by the *Watershed Enforcers* is: What is the sustainable safe yield of the SWP? In light of recent fish population surveys, it is clear that current pumping far exceeds the safe yield, and that pumping will need to be permanently reduced.

At the same time, it is widely known that the SWP is not able to deliver the full Table A allocations that were proposed in 1960 when the project was first approved. DWR's 2005 Reliability Report, used by planners to justify development activities throughout Southern California, indicates that 77% of the current Table A allocation will be available for use. Yet, this 77% figure is deeply flawed, particularly in light of recent information concerning the health of the Delta. The problem with proceeding under an unrealistic assumption of future delivery capabilities is that planners are relying on the promise of "reliable" water supplies that cannot be delivered without bending (or breaking) environmental requirements.

We propose that the Table A allocations be <u>permanently</u> reduced from the current 4.1 MAFY to reflect the biologically safe yield of the Delta. This will permanently eliminate all "paper water" from the system, enabling planners to make rational decisions about future development activities in Southern California. If DWR fails to do this, it will be setting the stage for yet another round of pumping wars as municipal users begin to demand the promised "paper water" that cannot be delivered.

The rest of this letter will discuss the problems in the Delta, the problems with the reliability of the SWP as it is currently being managed, and why the reduction of the Table A allocations is a good solution.

Problems in the Delta

It is now widely recognized that several species of fish in the Bay Delta, including the Delta smelt, splittail, winter run salmon, and several others, are on the verge of extinction. It is also virtually undeniable that one of the causes of fish decline is excessive export pumping from the Delta.

Several judicial rulings have found current and proposed approaches to managing the impacts of export pumping to be inadequate. For example, an October 2005 ruling by the Third District Court of Appeal overturned the CALFED Record of Decision. *In Re Bay-Delta Programmatic Environmental Impact Report Coordinated Proceedings*, (2005) 133 Cal. App. 4th 154. That decision requires analysis of an alternative that would reduce the export of water south of the San Francisco/San Joaquin Delta. If implemented, this alternative would curtail deliveries from the SWP. Similarly, a February 9, 2006 Third District Court of Appeal ruling, *State Water Resources Control Board* (SWRCB) Cases (2006) 136 Cal. App. 4th 674, in which Golden Gate Audubon prevailed, requires that existing salinity standards in the Bay Delta be upheld.[1] The courts are giving a clear message to DWR; the Delta crisis requires less pumping at Banks.

On April 26, 2007, a group of environmental organizations, led by the California Sportfishing Protection Alliance (CSPA), submitted a letter to Department of Fish and Game Director Ryan Broddrick, urging Fish and Game to deny DWR's pending request for a consistency determination under the California Endangered Species Act. (Attachment #1.) This letter very clearly delineates the fish crash in the Delta and why it is happening.

Despite crashing fish populations and continued rebukes from the courts, DWR and the Bureau of Reclamation propose to pump up to 27% more water out of the Bay-Delta as part of the South Delta Improvement Project (SDIP). This proposal is soundly critiqued by the CSPA in their comments submitted to DWR February 7, 2006. (Attachment #2.) In addition, the National Marine Fisheries Service has suspended formal consultation on the SDIP until more studies have been completed. (Attachment #3.) DWR should abandon this untenable plan in favor of a sustainable way forward, by setting a cap on Table A allocations that corresponds with a safe level of pumping at Banks.

SWP Water Reliability

Determining what is a safe level of pumping must coincide with an acknowledgement that the SWP has been unable to deliver more than half of the 4.1 MAFY promised in the SWP contracts.

The 2005 SWP Delivery Reliability Report is full of "paper water." "Paper water" is water that exists as "little more than a wish and a prayer." *Planning and Conservation*

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[1] A subsequent order by the SWRCB requires DWR and the CVP to shut down their pumps if the salinity standards are not met. SWRCB Order WR 2006-0006. This means that more water must be left in the San Joaquin River and the Bay-Delta and, consequently, that there will be less water to pump to southern California.

League v. DWR, (2000) 83 Cal. App. 4th 892, 915. While the SWP contracts promise allocations of up to 4.1 MAFY, in reality the average actual annual delivery between 1990 and 2004 was a mere 2.0 MAFY. However, rather than relying upon the average historical annual delivery of slightly less than half the promised allocation, the 2005 Reliability Report projects that, on average, 77% of the SWP Table A Allocation will be available. This projection, relied upon by planners throughout the state, is deeply flawed.

We have attached the December 19, 2005 comments on the deficiencies of the 2005 SWP Reliability Report submitted by Physicist and Systems Analyst Arve Sjovold. (Attachment #4.) Also attached are the December 22, 2005 comments on the deficiencies of the 2005 SWP Reliability Report submitted by PCL Water Program Manager Mindy McIntyre. (Attachment #5.)

One of the central flaws with the Reliability Report is its reliance on **CALSIM II,** a computer model that has been widely criticized by peer review studies. See "A Strategic Review of CALSIM II and its Use for Water Planning, Management, and Operations in Central California," by J. R. Lund, et al, December 4, 2003 (Attachment #6). Among other things, CALSIM II presumes groundwater is an unlimited resource. This leads to a false impression of what water is actually available.[2] More recently, "An Environmental Review of CalSim II" by Jeffrey T. Payne and David R. Purkey, November 2005, concludes "...we are left with the profound impression that [CalSim II] is not a tool that can -- under its current formulation -- fully address the legally required water management objectives. CalSim II holds that the environment is a constraint on system operations, not one of the objectives for which the system should be managed." (Attachment #9.)[3]

In addition, the Reliability Report fails to take into consideration the potential **impacts of global climate change.** The growing consensus of experts studying this issue is that global climate change will result in less snow, earlier melting of the snowpack, and more rain, all of which will lead to higher spring flows, rather than the snowpack acting as a reservoir as it has in the past. Rising ocean levels, which may lead to greater influx of salt water into brackish ecosystems, is another problem exacerbated by global climate change. This is elaborated in "Emissions Pathways, Climate Change, and Impacts on California." (Attachment #14.)[4]

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[2] See "Additional Comments on CalSim II Pertinent to the Temporary Restraining Order" by Arve Sjovold regarding the Injunction granted by the Court in the InterTie case. (Attachment #7.) In addition, we submit "Musings on a Model: CalSim II in California's Water Community," March 2005. (Attachment #8.)

[3] Also attached is a critique of CalSim II by Jan de Leeuw, Distinguished Professor and Chair CLA Department of Statistics, dated October 23, 2005 (Attachment #10), as well as three comment letters concerning CALSIM II modeling by Arve Sjovold: "Response to Director Johns' letter of September 22, 2005 on CALSIM II" (Attachment #11); "Some Insights on Water Deliveries to Settlement Contractors", October 24, 2004 (Attachment #12); "On the Adequacy of CALSIM II for Environmental Impact Analysis and SWP Reliability Analysis," August 12, 2004 (Attachment #13.) All of these documents clearly lay out the problems with reliance on CALSIM II as the predictor of reliability for the SWP.

[4] **DWR** recently issued a report titled **"Progress on Incorporating Climate Change Into Management of California's Water Resources"** (July 2006). In this report, DWR attempts to incorporate climate change into CALSIM. Arve Sjovold reviewed that report and concluded, "that it too was seriously flawed for the purposes intended. It does a decent job on reviewing the extant literature on climate change but its quantitative analyses have very little to do with the issues that attend climate change. For example, when they attempt to calculate the effect on stream runoff in the northern Sierra, they take gross estimates from the climate change models, use a more detailed runoff model (which may or may not be a good model) to

Article 18 (a) & (b) of the SWP Contracts

Article 18(a) of the SWP Water Contracts requires that agriculture take the first cutbacks in SWP deliveries during drought years.[5] **Article 18(b)** of the SWP Water Contracts states that DWR will only promise what it can actually deliver on a long-range basis, thus requiring the elimination of "paper water." The Monterey Amendments to the SWP Contracts attempted to eliminate both Article 18 (a) & (b) from the SWP Contracts without analysis of the consequences of doing so. The original Monterey Amendments were set aside in part for this very reason.

Permanently revising the Table A allocations to reflect the real environmental needs of the Delta will assist planners throughout the state by providing them a truly realistic picture of water supplies. Doing so will also go a long way toward resolving long-standing objections to the Monterey Amendments.

Solution to the Delta Problems

It is clear that the Courts and the scientific community both agree that too much water is being pumped from the Delta. We understand that the Metropolitan Water District (MWD), the largest SWP contractor with rights to half of the Table A allocations, recognizes that the Delta is in crisis and that new dams are not the answer. The SWP is the largest single user of energy in the state, reflecting the enormous amounts of energy required to pump SWP water up over the Tehachapi Mountains for Southern California. As global warming is caused in large part by CO_2 emissions, conservation of local water sources is the best way to cut back on these emissions and provide a cheaper and more reliable water supply. MWD recognizes this.

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develop a scale factor to ramp up peak runoff forecasts, but use this scale factor as a multiplier on a base year that is one of the driest in history. In effect, they show that the increase in runoff is not very large and they use their estimates of this increase to drive their quantitative studies of Delta behavior. I found practically nothing of value in their quantitative studies that really goes to the heart of the climate change problem." (Attachment #15.) Also significant here is the report by Michael Dettinger of the U.S. Geological Survey entitled "Climate Change and the Water supplies in the West." Mr. Dettinger is an expert on snowpack storage and his report shows that snowpack in the Sierra is in steep decline. (Attachment #16.) Also relevant here is the report from NASA showing the temperature rise in California in the last half of the 20th Century. (Attachment #17.)

[5] Article 18(a) is a very important safeguard for municipal water supplies. The California Water Code specifically states that urban users have a priority over agricultural users. Water Code Sections 106 and 106.5 provides:

> 106. It is hereby declared to be the established policy of this State that the use of water for domestic purposes is the highest use of water and that the next highest use is for irrigation.
>
> 106.5. It is hereby declared to be the established policy of this State that the right of a municipality to acquire and hold rights to the use of water should be protected to the fullest extent necessary for existing and future uses, but that no municipality shall acquire or hold any right to waste water, or to use water for other than municipal purposes, or to prevent the appropriation and application of water in excess of its reasonable and existing needs to useful purposes by others subject to the rights of the municipality to apply such water to municipal uses as and when necessity therefore exists.

How should DWR come up with an appropriate Table A cap? First, it must be acknowledged that it is not enough to maintain Table A Allocations at or near 2.0 MAFY, the average pumped from 1990 through 2004. Pumping at those rates has had devastating effects on the Delta. This must stop if the Delta is to be restored. The courts are mandating that alternative pumping scenarios that require far less exports from the Delta be thoroughly considered. These scenarios must be evaluated using robust, scientifically justifiable modeling. The SWP contracts were always meant to be a reflection of the "true safe yield" or the "firm yield" of the project. It is time to cut back the Table A Allocations to reflect this.

One way to significantly lower the total Table A allocations, and thereby reduce the requirements for exports from the Delta, would be to pursue retirement of the drainage impaired lands in the Western San Joaquin Valley served by the SWP. Table 1 below portrays a preliminary estimate of potential water savings in Tulare and Kern County within the SWP service area.

Table 1[6]

	Total Irrigated croplands in 2002(acres)[7]	**Drainage Impaired acreage in 2000 (acres)**[8]	**% of County Requiring Drainage Service**	**Estimated Contract Amounts (AF)**[9]	**Estimated Water Savings (AF)**
Tulare County	652,385	291,000	44.60%	1,304,770	581,927
Kern County	811,672	313,000	38.56%	1,623,344	625,961
Total	1,464,057	604,000	N/A	2,928,114	1,207,888

The Pelagic Fish Action Plan, a March, 2007 document by DWR and the California Department of Fish and Game, recommends reductions in pumping from the Delta of 1.66 MAFY.[10] **Both the SWP and the federal CVP are affected by these recommendations. Reducing the SWP 1990 -2004 average actual deliveries of 2.0 MAFY by 0.83 MAFY (half of the recommended cuts 1.66 MAFY cut), would give us a new average safe yield amount of 1.17 MAFY.**

It is widely known that there is no extra or "surplus" water any longer in California. In conjunction with the Table A reductions outlined above, it is essential to eliminate the concept of "surplus" water from the State Water Project contracts. Article 21 water, the so

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6 This table is drawn from a January 1, 2005 letter sent by the Trinity County Board of Supervisors to the DWR regarding the Draft Environmental Impact Statement/Report for the SDIP.

7 The acres of irrigated croplands is taken from the USDA farm census statistics report in 2002.

8 The acreage of drainage impaired acres is derived from a report by DWR produced as part of the 2000 San Joaquin Valley Drainage Monitoring Program. The acreages identified are for lands with high groundwater within 20 feet of the surface.

9 The contract amounts are figured by estimating 2 acre-feet per acre irrigated, most likely an underestimate.

10 1.66 mafy is the sum of the estimated "costs" of those water operations actions recommended in the Pelagic Fish Action Plan at pages 5-6 and 43-48 (Attachment #18.)

called "surplus" water feature of the SWP contracts must be removed from the contracts. This Article 21 water has been used to "game the system" for too long and must be eliminated from the contracts.

Using DWR and Fish and Game's own data, we recommend that the Table A Allocations for the SWP be permanently reduced to a level that ensures average annual deliveries do not exceed 1.17 MAFY.

Sincerely,

Carolee K. Krieger

Carolee K. Krieger, President
808 Romero Canyon Road
Santa Barbara, CA 93108
PH: (805)969-0824

Cc: Bill Jennings, Executive Director, California Sportfishing Protection Alliance
Ryan Broddrick, Director Department of Fish and Game
Tim Brick, President Metropolitan Water District Board of Directors
Jeff Kightlinger, Manager Metropolitan Water District
Pam Doduc, Chair, State Water Resources Control Board
Darrell Steinberg, Chair, Senate Natural Resources & Water Committee

Attachments:

1. CSPA group letter to Ryan Broddrick, Director Department of Fish and Game April 26, 2007 (15 pgs.)

2. "CSPA Comments on the South Delta Improvement Program, Draft EIS/EIR" by Bill Jennings, chairman and Executive Director, CSPA, 2/7/06 (50 pgs.)

3. Letter from NOAA National Marine Fisheries Service 1/11/07 re: SDIP (2 pgs.)

4. "Comments on the Draft SWP Reliability Report 2005" by Arve Sjovold, 12/19/05 (6 pgs.)

5. "Comments on Public Review Draft of the SWP Delivery Reliability Report 2005" by Mindy McIntyre, PCL Water Program Manager, 12/22/05 (20 pgs)

6. "A Strategic Review of CALSIM II and its Use for Water Planning, Management, and Operation in Central California" by A. Close, W.M. Haneman, J.W. Labadie, D.P. Loucks (Chair), J. R. Lund, D.C. McKinney, and J.R. Stedinger, December 4, 2003 (129 pgs)

7. "Additional Comments on CALSIM II by Arve Sjovold, Feb. 7, 2006 (1 pg)

8. San Francisco Estuary & Watershed Science, March 2005 "Musings on a Model: CALSIM II in California's Water Community." (13 pgs)

9. "An Environmental Review of CalSim II" by Jeffrey T. Payne and David R. Purkey, 11/05 (65 pgs)

10. "Response to Gerald Johns' Memo" by Jan de Leeuw, 10/23/05 (3 pgs)

11. "Response to Gerald Johns' Letter on CalSim II", by Arve Sjovold, 10/2/05 (3 pgs)

12. "Some Insights on Water Deliveries to Settlement Contractors" by Arve Sjovold, 10/24/04 (1 pg)

13. "On the Adequacy of CalSim II for Environmental Impact Analysis and SWP Reliability Analysis" by Arve Sjovold, 8/12/04 (7 pgs)

14. "Emissions Pathways, Climate Change, and Impacts on California", August 24, 2004 (6 pgs)

15. "Comments on DWR's Technical Memorandum", "Progress on Incorporating Climate Change into Management of California's Water Resources", July 2006 by Arve Sjovol 9/2/06 (5 pgs)

16. "Climate Change and Water Supplies in the West", Michael Dettinger of the USGS, (24 pgs.)

17. NASA Images April 17, 2007 (3 pgs.)

18. "Pelagic Fish Action Plan", March 2007, California Department of Water Resources and California Department of Fish and Game (9 pgs)

attachment #3

california water impact network

PRESS RELEASE

For Immediate Release

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C-WIN Demands Reduced Delta Pumping as answer to Delta Eco-Crash

California's Department of Water Resources (DWR) is mismanaging our precious Bay Delta and misrepresenting the amount of water that can be safely sucked from the Delta for delivery to farmers and developers. The California Water Impact Network (C-WIN), an organization dedicated to promoting sensible and sustainable water use throughout California, has asked DWR to dramatically and **permanently lower the total amount of water it pledges to deliver under the State Water Project (SWP) delivery contracts from the current level of 4.1 million acre feet per year to a level that ensures average deliveries will not exceed 1.2 million acre feet per year.** This reduction will help save the Delta and will give farmers and urban planners across the State a realistic picture of how much water will be available for use.

Currently, the SWP contracts pledge to deliver 4.1 million acre feet per year to water users south of the Delta, the same volume of water promised when the SWP was first approved in 1960. But, a lot has changed since 1960. "We now have a better appreciation of the importance of the health of the Delta and other aquatic ecosystems, an appreciation that is reflected in both state and federal environmental laws." says C-WIN's president, Carolee Krieger. As a result, Krieger notes, **"between 1990 and 2004, the SWP was, on average, able to deliver only 2.0 million acre feet of water per year, slightly less than half the promised allocation."**

To deliver water to central and southern California, DWR must pump it out of the Delta into storage and transport facilities. But, pumping kills fish and disturbs Delta ecosystems. Even though deliveries have been far lower than the proposed 4.1 million acre feet for many years, the Delta is still dying. Recent fish surveys have revealed that the Delta smelt, considered an indicator of the health of the Delta, has plummeted to record low numbers and is on the verge of extinction.

Many SWP Water Contractors are selling their water rights to urban areas in Southern California. What usually changes hands in such transfers is the full amount of water promised to the seller. But, because DWR has historically been unable to deliver a substantial portion of the promised amount, this leaves the purchaser, often a municipal water district, holding a large amount of what is known as "paper water." Paper water only exists on paper -- in the contracts -- and cannot be delivered. "The really dangerous thing about paper water is that it is being used to justify new construction throughout Southern California, even though it may never materialize," says C-WIN's Secretary, Dorothy Green, a well-known Southern California Water Activist.

According to language in each SWP Water Contract, DWR is required to reduce the amount of water it promises to deliver to reflect what it actually can deliver on a long-range basis. Doing so would get rid of the paper water. But, DWR has failed to obey the requirements of its own contracts.

C-WIN is asking DWR to permanently reduce the amount it promises in its contracts to reflect the real, biologically safe, capacity of the SWP to deliver the water. "If it fails to do so, new homeowners in Southern California may have nothing more than paper and hot air flowing from their taps," according to Carolee Krieger. "It is absolutely critical for the people of California to understand what it happening with paper water," says Dorothy Green. "Water policy in California is so complicated that the public is often left out of the decision making process," Green says, "but the use of paper water to fuel development in Southern California threatens to further erode our quality of life. It must be stopped."

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SDIP
CalSPA
(Mike J.)

California Sportfishing Protection Alliance
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7 February 2005

attachment #1

Mr. Paul A. Marshall
Department of Water Resources
South Delta Branch, Draft EIS/EIR Comments
1416 9th Street, 2nd Floor
Sacramento, CA 95814

Via email to: marshall@water.ca.gov and sdip_comments@water.ca.gov

RE: CSPA Comments on the South Delta Improvements Program, Draft Environmental Impact Statement/Environmental Impact Report

Dear Mr. Marshall:

The California Sportfishing Protection Alliance, San Joaquin Audubon and Watershed Enforcers (hereinafter, CSPA) submit the following comments on the Draft Environmental Impact Statement/Environmental Impact Report (DEIS/R) of November 2005, by the California Department of Water Resources (DWR) and the US Bureau of Reclamation (BOR) concerning the South Delta Improvements Program (SDIP). We incorporate by reference the comments submitted by the Planning and Conservation League, Northern California Counsel of the Federation of Fly Fishers, Friends of Trinity River, California Trout and Richard Izmarian. We also incorporate the attached comments concerning the inadequacies of the DEIS/R's assessment of water quality impacts by Drs. G. Fred Lee and Ann Jones-Lee (Attachment 1).

great!

The environmental assessments for virtually every previous significant project in the Delta have promised benign or beneficial effects. All exacerbated existing conditions. It is frankly astonishing that, in the midst of attempts to understand the causes of the collapse of the Delta's pelagic fisheries, DWR has proposed significantly increased export pumping accompanied by a major modification of the hydrologic regime in the south Delta on the basis of a seriously flawed, inadequate and legally deficient document. That DWR and BOR are aggressively pushing this project at a time when numerous species in the Delta are in precipitous decline, with several hovering on the brink of extinction, speaks volumes about the values and intentions of its proponents.

The Administrative Record for the SDIP must comply with the National Environmental Policy Act (NEPA) and the California Environmental Quality Act (CEQA) and carry out the statutory duty to provide decision-makers and the general public with a clear understanding of the consequences of the project.

An EIR is "an environmental 'alarm bell' whose purpose it is to alert the public and its responsible officials to environmental changes *before* they have reached ecological points of no return." *Village Laguna of Laguna Beach, Inc. v. Board of Supervisors* (1982) 134 Cal. App. 3d 1022, 1027 (emphasis added). Beginning with its artificial segmentation of the proposed project through to its failure to evaluate a reasonable range or project alternatives, the DEIS/R fails to provide an accurate depiction of the many significant environmental impacts that will result from approval of the SDIP. The massive length of the DEIS/R does not reflect a depth of environmental analysis, but instead impedes a comprehensive understanding of the project's impacts. This letter details some, but not all, of the inadequacies in the DEIS/R, which include:

- The document is based upon the "Biological Opinion (BO) on the Long-Term Central Valley Project (CVP) and State Water Project (SWP) Operations Criteria and Plan (OCAP)", which has been found faulty by an independent technical review team convened by the CALFED Bay-Delta Program whose findings were made public January 3, 2006. (Attachment 2) A report by the Department of Commerce's Inspector General also found the BO process violated government procedures (Attachment 3).

- The document does not consider an alternative that **reduces** exports from the Delta, per the Third District Court of Appeals Decision (RCRC et al v State of California, Attachment 4), which sets aside the CALFED PEIR because the PEIR improperly fails to discuss an alternative that requires reduced exports of water from the Delta.[1]

- Similar to the CALFED PEIR and the Third District Court of Appeals Decision (RCRC et al v State of California), the document does not adequately disclose the environmental impacts of diverting water from various potential sources to meet the CALFED Program's goals. In particular, the analysis of impacts to upstream reservoirs, upstream river fisheries and upstream recreation are not only inadequate, but grossly misleading.

- The larger CALFED program, which includes SDIP, CVP long-term contract renewal, the so-called "Napa Proposal" and other elements to integrate CVP and SWP operations requires an EIS/EIR which amends the 1986 Coordinated Operating Agreement between DWR and BOR to include the regulatory baseline as it exists today prior making long term, potentially irretrievable, commitments of natural resources by building the barrier program in the Delta.

- The SDIP DEIS/EIR is premature in assuming that ever-larger deliveries of water to the San Luis Unit of the CVP can be justified, as the ROD for the San Luis Unit Drainage Re-Evaluation has not been completed. The National Economic

[1] Although the Supreme Court recently granted review of this case, the reasoning and conclusions of the Court are based on well-established CEQA law.

Analysis for that project identified that land retirement would be the most cost effective alternative, which could actually allow for **reduced** Delta exports.

Based on myriad inadequacies, prudence and a decent respect for the Delta Estuary we recommend that DWR and BOR withdraw the proposed DEIS/R for this project. We also request that the comment period be extended another 30 days in order to allow adequate time to review this complex and lengthy document.

I. The DEIS/R Improperly Defines the Proposed Project.

In order for an EIR to adequately evaluate the environmental ramifications of a project, it must first provide a comprehensive description of the project itself. "An accurate, stable and finite project description is the *sine qua non* of an informative and legally sufficient EIR." *San Joaquin Raptor/Wildlife Rescue Center v. County of Stanislaus* (1994) 27 Cal. App. 4th 713, 730 (quoting *County of Inyo v. City of Los Angeles* (1977) 71 Cal. App. 3d 185, 193). As a result, courts have found that even if an EIR is adequate in all other respects, the use of a "truncated project concept" violates CEQA and mandates the conclusion that the lead agency did not proceed in the manner required by law. *San Joaquin Raptor*, 27 Cal. App. 4th at 729-30. In particular, an inadequate project description hinders the evaluation of project alternatives in violation of CEQA.

The proposed South Delta Improvement Program, which has been promoted as a comprehensive solution to problems in the South Delta, and described as such in the CalFed Delta Improvements Plan, is arbitrarily divided into two stages:

- Stage I is presented as the selection of the physical/structural component of the program, the preferred alternative being the construction of four permanent physical barriers, and operation within the existing export constraints of the two water projects (CVP and SWP).

- Stage 2 is presented as the selection of a preferred operational component for the program. This selection process will follow the selection of the alternative in Stage 1, and will be subject to a Draft Supplemental EIS/EIR and a full public review. It is at this stage that the relaxation of the existing COE export constraints will be addressed.

The proposed staging approach (see ES-9) does not allow for a complete discussion of key elements such as alternatives to the proposed operation project. Specifically, each of the alternatives evaluated assumes that Stage 2 will include the full diversion of 8500 acre feet. The operation studies included in the Draft EIR/EIS, in a perhaps revealing way, do not include an alternative that conforms to the staged decision process. Operation studies described in this document include:

No Project	6680	No barriers, dredging, or ag. diversions
Missing Alt.	**6680**	**Full Barriers, dredging and ag. diversion**
2A	8500	Full Barriers, dredging, and ag. diversions
2B	8500	Full Barriers, dredging, and ag. diversions
2C	8500	Full Barriers, dredging, and ag. diversions

3B	8500	No Grantline Canal Barrier, dredging, and ag. div.
4B	8500	No Agricultural Barriers, dredging, and ag. div.

It is clear that an alternative (the "Missing Alt." shown above in bold, underlined) which includes the barriers, dredging, and agricultural diversion extensions (physical/structural component), but which is limited to the 6680cfs pumping limitation (no operational component), is missing from the mix. Therefore it will be impossible to separate the effects of Stage 1 from Stage 2 in the analysis.

The DEIS/R further undermines the effectiveness of the project description through its reliance on the artful use of semantics begins to describe the water transfers. For example, the DEIS/R separates the CVP/SWP contract water deliveries, from the EWA water, the refuge water supplies, and the water transfers for other parties. Thus, the document states that the effects are limited to a 1% to 3% increase in CVP/SWP contract deliveries and for the environmental water (Page ES-5). Yet another 2% increase is then subsequently assigned to water transfers. The Estuary is affected by the whole of the exports, and this "piece-mealing" of the analysis is inappropriate. The analysis should be based on the effects of the 3% to 5% combined increase in exports.

The narrow definition of the operational component of SDIP to increasing exports in four versions of 8,500 cfs does not allow a thorough discussion of alternative methods of increasing water supply reliability for CVP and SWP export contractors. Despite the DEIS/R's claim that the alternatives were developed through a "stakeholder process" the range of alternatives is far too narrow and was focused only on increasing exports to 8500 cfs at the SWP pumps in the Delta. This narrow focus was inherent in naming the stakeholder group "the 8500 Stakeholder Process" at DEIS/R Vol. 1a, 2-9.

In the face of the State Appeals Court ruling on the CalFed EIS/R and ROD we are astounded to find that the document does not consider reductions in exports from the Delta as a means of solving the south Delta problems. The State Appeals Court was quite clear on this issue, and this point alone requires the preparation of a new draft, which includes and analyzes the relevant environmental improvement from choosing such an alternative.

Yes

II. The Long Term CVP/SWP SDIP/OCAP BO is Inadequate

The SDIP project is based on Endangered Species Act compliance through the CVP/SWP OCAP. A revised BO should be prepared with adequate analyses to determine jeopardy to listed species, including winter and spring run Chinook, steelhead, and Delta smelt. An independent CBDA sponsored review by a team of 6 scientists recently concluded that the SDIP-OCAP BO for salmon had the following deficiencies:

1. **Global climate change was not considered.** The BO assumes that the climate and hydrologic regime during the last century will persist into the future. The Panel does not believe that global climate change (e.g.,

temperature warming), and the consequent temperature and hydrological changes, received adequate treatment in the BO. This deficiency resulted in an important uncertainty being ignored that could affect the characterization of the risk to the ESUs.

2. **Variability in ocean productivity, and its affect on fish production, was not incorporated into the analyses.** The current status of the listed populations is, in part, an outcome of recent favorable ocean conditions. What will the status of listed populations be under less favorable conditions that may occur in the near future? By not including variability of ocean conditions in its analysis, the BO does not adequately address whether or not the listed populations are sufficiently large to survive a period of poor ocean conditions.

3. **Unknowns or uncertainty were either not adequately incorporated into the analyses, or their incorporation was not clearly explained.** In some cases, uncertainties were simply ignored or their consideration was deferred to other future analyses or other in-progress biological opinions. For example, Table 9 in the BO (page 193) summarizes the effects of the proposed project on the listed ESUs, but Table 9 fails to list eleven additional effects mentioned in the text of the BO. Ignoring or deferring the consideration of these effects in analyses does not give the listed species the required benefit of the doubt.

4. **Some models and analyses appeared to be flawed.** The application of monthly temperature models to anadromous fish studies is a point of concern. Of particular concern is the adoption, with little discussion, by NMFS of these monthly results both for assessing potential impacts and for setting thermal criteria. In addition, the data used to develop relationships between water temperature and salmon gamete, egg, and alevin mortality was not the best available.

5. **Greater consideration should be given to genetic and spatial diversity in the ESUs.** Too little consideration was given to the genetic and spatial diversity aspects of the ESUs. The Central Valley Technical Recovery Team noted that the "dependent" populations of spring Chinook and steelhead occupy marginally suitable habitats that either depend on migrants from the nearby streams or operate as a meta-population in which each stream is not individually viable, but the group persists. These dependent populations are a valuable resource because they exist in marginal environments, may contain valuable genetic attributes (e.g., higher temperature tolerance), and may serve as links with other populations in ways that increase the viability and resiliency of the ESUs over long time scales. The BO did not adequately treat the genetic and spatial diversity aspects in their analysis.

The DEIS/R may not rely on an inadequate environmental document to address and mitigate the environmental impacts of the SDIP. *Santa Clara River v. Castaic Lake* (2002) 95 Cal. App. 4th 1373. Clearly, the BO for the SDIP is inadequate and must be revised and completed prior to release of a new DEIS/R. In order to fully disclose impacts and mitigation measures, the revised BO must be completed prior to release of the new DEIS/R.

III. The DEIS/R Fails To Consider A Reasonable Range Of Alternatives

"An EIR for any project subject to CEQA must consider a reasonable range of alternatives to the project, or to the location of the project, which (1) offers substantial environmental advantages over the project's proposal . . .; and (2) may be feasibly accomplished in a successful manner considering the economic, environmental, social and technological factors involved." *Citizens of Goleta Valley v. Board of Supervisors* (1990) 52 Cal.3d 553, 566. "The discussion of alternatives shall focus on alternatives to the project or its location which are capable of avoiding or substantially lessening any significant effects of the project, even if these alternatives would impede to some degree the attainment of the project objectives, or would be more costly." CEQA Guidelines § 15126.6(b).

The DEIS/R must consider feasible alternatives that would obviate the necessity for increased export capacity. These include: 1) evaluation of the cost effective retirement of marginal farmland (including, but not limited to the selenium-laced soils of Westlands), 2) comprehensive agricultural and urban water conservation (including recycling, reclamation and the capture and treatment of surface/stormwater runoff), and 3) implementation of an aggressive desalination program in Southern California. It is likely that these alternatives would be environmentally superior and considerably more cost effective than the billions of dollars required for the SDIP. The cost of desalination is approaching the $750 to $1,000 range. Point and non-point control programs, like TMDLs, are problematic and prohibitively expensive. Conservation is clearly more cost effective than heavily subsidized export water. The DEIS/R should also examine alternatives that would reduce or eliminate the need for dredging (i.e., setback levees). Should the aforementioned alternatives be rejected, the DEIS/R must contain a discussion of why they were considered infeasible.

desal brackish waters or waste water

In October, the California Third District Court of Appeals set aside the CALFED ROD because, among other things, the PEIS for CALFED did not consider an alternative that **reduces** exports from the Delta. In January, the California Supreme Court agreed to review the case. It is therefore shocking to see that similar to the flawed CALFED PEIS, the SDIP DEIS/R does not contain an alternative that reduces Delta exports. This is particularly arbitrary since the first phase of the 8500 cfs project is supposedly only for fish and wildlife purposes and less pumping would seem to be a feasible alternative to meet the purpose and need or objective of the physical barriers project. This is a serious deficiency in the SDIP DEIS/R and must be remedied by development of an alternative that does not require an increase in use of the SWP's pumping capacity at Clifton Court. The "less export" alternative should be evaluated in light of alternative water supplies for

Delta exporters available and identified in numerous public reports, including DWR Bulletin 160-05.

The DEIS/R's justification for increased exports south of the Bay-Delta Estuary is predicated upon Bulletin 160-98. However, the recently released California Water Plan Update 2005 demonstrates that, under current trends, south of Delta water demands actually decrease in 2030, even accounting for the increased population. The Water Plan Update provides a reasonable scenario under it's Less Resources Intensive assumptions that water use statewide could decrease by up to 500 million acre feet, even without additional water conservation efforts taken by California water agencies. Additionally, a recent report by the Pacific Institute titled *California Water 2030: an Efficient Future* demonstrates that California water use in 2030 could be 20% below 2000 levels, even with a growing population and a healthy economy. Basing water demand upon outdated and discredited information while ignoring more recent relevant information is misleading and unacceptable. The DEIS/R must be withdrawn and reanalyzed using a reduced export alternative.

CSPA supports Trinity County's suggestion for development of a "Land Retirement Alternative" which returns water to the environment and other water users as follows:

A revised SDIP DEIS/R should expand on Appendix A of the Trinity River Fishery Restoration Supplemental EIR (shown below revised as Table 1). Table 1 portrays a rough estimate of the potential water savings associated with the retirement of lands within the San Luis Unit, Delta-Mendota Canal Unit and the San Joaquin River Exchange Contractors of the Central Valley Project that are expected to require drainage service. The purpose of the Trinity County analysis was to estimate an amount of CVP water that could be obtained from the retirement of drainage-impacted lands in the 3 units of the CVP. The water savings would then be dedicated to increase cold-water storage, drought protection, and recreational use in upstream reservoirs. Use of this water should be dedicated to environmental restoration, water quality, or other water users as needed. The total land with drainage problems is 376,751 acres in the water districts identified below in Table 1, but other problem areas also exist outside of the SLU and DMC areas, as identified in Table 2 below.

Westlands

careful

The analysis below shows that land retirement could save 793,056 AF in total CVP contracted water, which would have been an actual reduction in demand of 568,373 AF in 2002, the same year as the unprecedented Klamath Fish Kill on the Trinity River, one of the CVP source rivers. Every increasing diversion from the Delta export projects effect water conditions on all Central Valley Rivers and are causing a decline in species numbers and habitat quality. Permanent land retirement and dedication of water to other CVP project purposes would result in significant benefits from reduced pollution from drainage water, reduced CVP project power usage, increased ability to meet various water quality standards, increased water storage, increased M&I water supplies, and more water for environmental needs such as fishery flows and wildlife refuges. Land retirement could also be the basis for an alternative that reduces exports from the Delta, per the Third District Court of Appeals decision on the CALFED PEIR.

great!

Table 1 from the Draft Trinity River Fishery Restoration Supplemental Environmental Impact Report (Trinity County 2004, as amended 1/24/05 and 2/16/05)

CVP

	Acres	Acres Requiring Drainage Service	% of District Requiring Drainage Service	Max CVP Contract Amount (AF)	Max CVP Contract Water Savings (AF)	2002 CVP Contract Deliveries (AF)	2002 CVP Water Savings (AF)
Broadview Water District	9,515	9,515	100.00%	27,000	27,000	18,588	18,588
Panoche Water District	39,292	27,000	68.72%	94,000	64,593	66,743	45,863
Westlands Water District	***604,000***	***298,000***	***49.34%***	***1,154,198***	***569,455***	***776,631***	***383,172***
Eagle Field	1,438	1,435	99.82%	4,550	4,542	2,869	2,864
Mercy Springs	3,589	2,417	67.35%	2,842	1,914	4,679	3,151
Oro Loma	1,095	,1095	100%	4,600	4,600	3,173	3,173
Widren	881	881	100%	2,990	2,990	2,094	2,094
Firebaugh	23,457	23,457	100%	85,000	85,000	85,000	85,000
Cent. Cal ID	149,825	4,951	3.30%	532,400	17,569	532,400	17,569
Charleston Drainage District (portion of San Luis WD with drainage problems)	4,314	3,000	69.54%	8,130	5,654	Not avail	Not avail
Pacheco Water District	5,175	5,000	96.62%	10,080	9,739	7,137	6,896
Total	842,581	376,751	NA	1,925,790	793,056	1,499,314	568,370

Table 1 above was derived by obtaining acreage information for each district through Chris Eacock at the Bureau of Reclamation (USBR) in Fresno. The number of acres requiring drainage by 2050 was taken from estimates in the San Luis Drainage Feature Evaluation, Plan Formulation Report, USBR, December, 2002 (pages 2-5 and 2-6). The maximum water savings associated with the retirement of these lands was calculated by multiplying the maximum contract amounts for each district by the percent of that district requiring drainage. Contract amounts were taken from a list of CVP contracts provided by Reclamation. Each district's total contract amount was calculated by adding all of its water contracts if more than one contract exists.

Westlands gets subsidies 2002 over $100 mill

According to information we have received from the Environmental Working Group, water and crop subsidies to Westlands in 2002 amounted to over $100 million. If approximately half of Westlands, as well as those impacted lands in other drainage-problem districts such as Broadview, Widren, Mercy Springs, Panoche, Pacheco and others were retired, it would free up hundreds of thousands of acre-feet of water, as well as significantly reduce water and crop subsidies by tens of millions of dollars a year. Full analysis of such an alternative would provide meaningful disclosure to decision makers and the public about the true costs of delivering water to these problem lands.

excellent

SWP

Table 2

	Total Irrigated croplands in 2002(acres)	Drainage Impaired acreage in 2000 (acres)	% of County Requiring Drainage Service	Estimated Contract Amounts (AF)	Estimated Water Savings (AF)
Tulare County	652,385	291,000	44.60%	1,304,770	581,927
Kern County	811,672	313,000	38.56%	1,623,344	625,961
Total	1,464,057	604,000	N/A	2,928,114	1,207,888

Table 2 above portrays a very preliminary estimate of water savings in Tulare and Kern County within the SWP service area. The acres of irrigated croplands in these Counties was taken from the USDA farm census statistics report in 2002. The acreage of drainage impaired acres is derived from a report by CA Dept of Water Resources, the 2000 San Joaquin Valley Drainage Monitoring Program. The acreages identified are for lands with high groundwater within 20 feet of the surface. The contract amounts were figured by estimating 2 acre-feet per acre irrigated, most likely an underestimated amount. Further investigation is needed to verify and refine these numbers, but clearly there is adequate justification to remove these lands from irrigation due to continuing drainage problems and salinization of land, in violation of Water Code Section 100- Wasteful and Unreasonable Use of Water.

Finally, the DEIS/R not only fails to suggest reasonable alternatives to the barriers project that would better solve the objectives of a real South Delta Improvement program-land retirement and less export, it also fails to evaluate the impacts of increasing the capacity to deliver export water to drainage impacted land.

excellent

IV. The Selection of Alternatives Biases the Analysis, Predetermines Results and Fails to Achieve Identified Purposes of the Project.

The DEIS/R unreasonably narrows the project purposes to eliminate reasonable alternatives. The identified purposes of the project are defined as:

1. Reduce the movement of San Joaquin River watershed Central Valley fall/late fall-run juvenile Chinook salmon into the south Delta via Old River.

2. Maintain adequate water levels and, through improved circulation, water quality available for agricultural diversions in the south Delta, downstream of the head of Old River; and

3. Increase water delivery reliability for SWP and CVP water contractors south of the Delta and provide opportunities to convey water for fish and wildlife purposes by increasing the maximum permitted level of diversion through the existing gates at CCF to 8,500 cfs.

However, other than the no-project alternative, the only alternatives considered are construction of permanent barriers and increasing exports. This disingenuously predetermines the outcome and inappropriately excludes feasible less environmentally damaging alternatives. Arbitrarily excluding less environmentally damaging alternatives fails to meet the required scope of CEQA and NEPA.

In any case, project implementation will not meet the purposes of the project.

1. Construction of a Head-of-Old-River barrier may enable out-migrating salmonids to continue down the San Joaquin River rather than being drawn down Old River. However, DWR's particle tracking model and Vogel's radio-telemetry studies establish that San Joaquin out-migrants will subsequently be drawn down Turner and Columbia Cuts to the state and federal project pumps. Out-migrant salmonids still will not reach Chipps' Island.[2] Reducing the movement of salmonids into the south Delta via Old River accomplishes no environmental purpose if they escape Old River only to be drawn to the pumps via Turner and Columbia Cuts.

2. Likewise, project implementation will not improve water levels and water quality in the south Delta. As we discuss below, the DEIS/R acknowledges that water levels will decrease in the south Delta and any perceived improvement in water quality is speculative and lost in the noise of the modeling.

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[2] http://calwater.ca.gov/Programs/Conveyance/FTDDCCTDF/Sept15_2005/TDF_Presentation_Vogel_9-15-05.pdf ; http://science.calwater.ca.gov/pdf/2002_Salmonid_Workshop_Summary.pdf (page 37) ; Vogel D. 2001. Juvenile Chinook salmon radio-telemetry study in the northern Sacramento-San Joaquin Delta, January – February 2000. Final project report submitted to U.S. Fish and Wildlife Service, Stockton, Calif. Red Bluff (CA): Natural Resources Sciences, Inc. 32 p; and Vogel D. 2002. Juvenile Chinook salmon radio-telemetry study in the southern Sacramento-San Joaquin Delta, December 2000 – January 2001. Final report submitted to the U.S. Fish and Wildlife Service, Stockton, Calif. Red Bluff (CA): Natural Resources Sciences, Inc. 27 p.

3. The only project purpose that is potentially realized by project implementation is increased water exports. However, increasing exports is not likely to improve water supply reliability as DWR's Draft 2005 Reliability Report predicts that as water deliveries increase, reliability actually decreases. While the Reliability Report contains serious flaws that must be corrected, DWR has elected to use the report analysis as the method for determining project water supply reliability. The Reliability Report shows that the SWP is estimated to be capable of delivering 1.2 maf about 90% of the time under DWR's 2025 modeling while deliveries of around 3 maf are only reliable in less than 70% of years. The DEIS/R must analyze how increasing exports under the proposed alternatives affects the reliability curve of the SWP.

bad

V. The DEIS/R Fails To Provide An Adequate Discussion of the Project Setting and Therefore Fails to Properly Analyze SDIP impacts to Fisheries

"Accurate and complete information pertaining to the setting of the project and surrounding uses" is critical to an evaluation of a project's impact on the environment. *San Joaquin Raptor/Wildlife Center v. Stanislaus County* (1994)27 Cal. App. 4th 713, 729; *See also Friends of the Eel River v. Sonoma County Water Agency* (2003) 108 Cal. App. 4th 859, 875 ("incomplete description of the Project's environmental setting fails to set the stage for a discussion of" significant effects). As detailed below, the DEIS/R does not provide a complete analysis of the current state of the Delta and therefore cannot adequately address the impacts of the SDIP on the environment.

Abundance indices calculated by the Interagency Ecological Program (IEP) suggest recent marked declines in numerous pelagic fishes and zooplankton in the upper San Francisco Estuary (the Delta and Suisun Bay). These low levels were unexpected given the relatively moderate hydrology over the past three years. IEP proposes to augment existing monitoring, perform new data analyses, and conduct special studies to investigate whether there is a new threat to pelagic fish and their prey, and if so, what has caused it.

The IEP conceptual model includes at least three general factors that may be acting individually or in concert to lower pelagic productivity: 1) toxins; 2) invasive species; and 3) water project operations. The overall approach adopted in 2005 is a screening-level study to better define the degree to which each of these factors may be responsible individually, in sequence, or in concert for the apparent step-changes. The workplan is based on a "triage" model to identify the most likely causes, and to assign priorities to projects on the basis of where funds and resources can be best used. Results also may shed additional light on causes of long-term declines in several of the affected species. Several of the lines of inquiry will be managed on an adaptive basis in that information will be examined as it is made available and depending on the results, increasingly focused studies will be conducted in 2006 and later years. SDIP needs to wait for the results of those studies before effective mitigations can be designed and implemented.

As noted, the abundance indices calculated by the IEP Fall Mid-water Trawl survey (MWT) show marked declines in numerous pelagic fishes in the upper San Francisco Estuary (the Delta and Suisun Bay). The abundance indices for 2002-2004 include record lows for delta smelt and age-0 striped bass and near record lows for longfin smelt and threadfin shad (Bryant and Souza 2004; Hieb et al. 2005). Data from another IEP monitoring survey, the Summer Tow Net Survey (TNS), support the MWT findings: TNS abundance indices for striped bass and delta smelt were among the lowest indices in the 45-yr record. In contrast, the San Francisco Bay Study did not show significant declines in its catches of marine/lower estuary species (Hieb et al. 2004; Hieb et al. 2005). Based on these findings, the problem appears to be limited to fish dependent on the upper estuary.

In addition to the declines in fish species, IEP monitoring also found declining abundance trends for zooplankton with a substantial drop in calanoid copepod abundance in 2004. Calanoid copepods such as *Eurytemora affinis* and *Pseudodiaptomus forbesi* are the primary food for larval pelagic fishes in the upper estuary (IEP 1987; Meng and Orsi 1991; Nobriga 2002) as well as older life stages of planktivorous species such as delta smelt (Lott 1998). Conversely, the invasive cyclopoid copepod *Limnoithona tetraspina*, which may be a poor food source for fish and an intraguild predator of calanoid copepods, is increasing in abundance and continues to be the most abundant copepod in the estuary (Mecum 2005).

While several of these declining species - including longfin smelt, juvenile striped bass and calanoid copepods have shown evidence of a long-term decline - there appears to have been a precipitous "step-change" to very low abundance during 2002-2004. This observation is supported by initial statistical analyses of the MWT data (Manley in prep.). Moreover, the record or near-record low abundance levels are remarkable in that the hydrological regime in the San Francisco Estuary was moderate during this period. Many estuarine organisms including longfin smelt and striped bass typically produce poor year classes in dry years (Jassby et al. 1995); delta smelt abundance is generally lowest in very wet or very dry years (Moyle et al. 1992). Thus, the moderate hydrology during the past three years should have supported at least modest production.

The fact that multiple pelagic species at more than one trophic level seem to show the 2002-2004 step decline is of particular concern. Regardless of whether the observations over the past three years are remarkable, the fact that the efforts of the California Bay-Delta Authority (CDBA) have apparently not arrested long-term declines in some pelagic species indicates that additional efforts are needed to identify what limits pelagic fisheries production in the upper estuary. Over the past decade, CBDA activities have resulted in a major shift in the timing of water exports, the development of an Environmental Water Account, and construction of habitat restoration projects. Additional information about the factors affecting pelagic organisms is needed before alternatives are designed for the SDIP, and provide guidance for future activities in the upper estuary including step 2 of SDIP.

Kimmerer (2002a) showed that water project operations have resulted in lower winter/spring inflow and higher summer inflow to the Delta. As noted previously, the CBDA actions have restored some spring inflow, but have also increased summer inflows to meet increasing summer export demands. This shift was implemented based on the assumption that it would be more protective to sensitive early life stages of key estuarine fishes and invertebrates. However, it is possible that high export during summer-winter months has unanticipated food web effects by exporting biomass that would otherwise support the estuarine food web. Other possible mechanisms include increased entrainment of fishes during the summer-winter months, or a reduction in habitat quality downstream (e.g. less area of the appropriate salinity). Total annual exports have continued to increase under the CBDA. It is also possible that the total volume diverted on an annual basis influences estuarine productivity (Livingston et al. 1997, Jassby et al 2002). The FEIR/S must disclose such information, analyze potential impacts from increased usage of pumping capacity in light of the uncertainties inherent in installation of permanent barriers and making operational changes to include further use of 8500 cfs export capacity.

We also suggest that you further evaluate impacts of SDIP in light of knowledge that in the past few years, more water has been exported during the summer (July-September) and the winter (December-March) than before, in part to compensate for conservation-driven export reductions in spring (April and May). There have been other changes in water project operation changes, which may also have had unexpected biological side-effects (e.g. export of more primary production). The purpose of ongoing scientific investigation is to closely examine recent changes in water project operations to identify effects potentially strong enough to account for the apparent step change in pelagic fish species abundances since 2001.

water project operations changes

Other historical changes in water project operations should also be disclosed and analyzed to support the decision-makers understanding of historical population dynamics for fish species in the Bay/Delta and to advance knowledge of the role of water project operations in the long-term decline of certain pelagic fish species. "Dramatic increases in winter CVP and SWP salvage occurred contemporaneously with recent declines in several pelagic fish species. These unexpected increases in salvage density coincide with the step decline pelagic fishes in 2002. The *Winter Adult Entrainment Hypothesis* presently being studied by the CALFED program posits that these events are causally linked. Evidence for this hypothesis includes:

1. There appears to have been a step increase in salvage density of adult delta smelt, threadfin shad and longfin smelt between 2001 and 2002. This increase is consistent with recent-year changes in winter water export operations. See Herbold et al

2. There appears to have been a step decrease in the Fall Mid-water Trawl indices of adult delta smelt, threadfin shad, and longfin smelt between 2001 and 2002. See Study Component 2i report by Manly and Chotkowski for details.

3. Winter exports from the CVP and SWP have increased since the late 1990s. See Study Component 2h report by Simi and Ruhl for details.

Key

Increased winter entrainment of delta smelt, long-fin smelt and threadfin shad represents a loss of the pre-spawning adults and all potential progeny. This means on a per capita basis loss of each adult fish may be equivalent to the loss of hundreds or even thousands of juveniles later in the year. Because an entrainment impact specifically affecting adult fishes has the potential to be strong, we regard finding an explanation for this coincidence a high priority.

The main sorts of explanations for why winter salvage densities may have increased since 2002 include: (1) the source of exported water has been changed to an area where more of these fishes occur during the winter; (2) the affected fishes have moved to areas from which exports are drawn; and/or 3) winter exports have increased past some sort of hydrodynamic threshold below which fish were better able to avoid entrainment. We expect well-documented answers in the FEIS/R to questions like: How have recent (1995 – 2004) water project operations policy changes changed delta hydrology? "Hydrology" is meant here to include the volume, timing, and pattern of input flows into the delta, delta outflow, exports, and operation of various water project gates and barriers. We also ask: which, if any, of the changes might plausibly have contributed to, or caused, a step change decrease in pelagic fishes abundance since 2001? We also want to know how the barriers will effect the questions above.

Very good

We suggest that you redo the DEIR/S to adopt the following assumptions for your new analysis since the on-going IEP study is using them:

1. Stressor effects on pelagic populations are highest during the summer period.
2. Ideal" hydrology in 2005 will not result in substantial increases in the abundance of pelagic fish and calanoid copepods.
3. Stressor effects have increased during the summer period relative to historical data.

We further suggest that you redo the inadequate analysis in the DEIS/R of the potential for the SDIP to aggravate the unfolding pelagic fish crash. A thorough analysis of the direct and indirect effects of building the barriers on reverse flows, water levels, entrainment of salmon and smelt, predation, residence time of water in the South Delta, and hydrodynamic changes in the South Delta caused by the new permanent barriers should be prepared. The analysis that presently exists in the DEIS/R is not adequate to justify selection of any of the alternatives presented and will result in misleading the decision-makers about the environmental impacts of the project and what course to take in their respective decision documents.

VI. The DEIS/R Fails to Adequately Analyze Project Impacts.

An EIR must provide information about the magnitude and type of environmental impacts; it may not, as this draft does, simply speculate that there may be impacts and hope for the best. *See Stanislaus Natural Heritage Project v. County of Stanislaus* (1996) 48 Cal. App. 4th 182, 196-97. An EIR must also provide "information about how adverse the adverse impact will be." *Santiago County Water District v. County of Orange* (1981) 118 Cal. App. 3d 818, 831. This information must contain facts and analysis, not the agency's bare conclusions . . . .") *See Citizens of Goleta Valley*, 52 Cal. 3d at 568.

As detailed below, the DEIS/R fails to provide an adequate analysis of a range of project impacts. This failure renders the DEIS/R inadequate and requires that the DEIS/R be revised and recirculated prior to project approval.

1. Water Quality Impacts from SDIP were inadequately disclosed and considered in the DEIS/R.

The analysis of water quality impacts in the DEIS/R is woefully inadequate. The SDIP must be consistent with and comply with requirements of the federal Water Pollution Control Act and California's Porter-Cologne Water Quality Control Act. Delta water quality must not be sacrificed at the altar of increased exports. The historical export of South Delta water has fundamentally altered the movement of pollutants throughout the Delta. Rapid population growth in the South Delta is increasing the mass loading of numerous pollutants (i.e., wastewater, stormwater, illegal dumping). Implementation of the SDIP will further alter the distribution and concentration of these constituents. The majority of water quality monitoring has primarily focused on salinity, with little emphasis on other water quality parameters. Sufficient baseline field data does not yet exist to adequately calibrate/verify models and evaluate project effects on the rainbow of water quality constituents (i.e., virtually the entire suite of organic and inorganic pollutants) that will likely be affected by the project. A rigorous water quality analysis should precede project evaluation, alternative formulation, and implementation.

As previously noted, attached and included as a part of these comments is the assessment titled *Comments on the Draft Environmental Impact Statement Environmental Impact Report, South Delta Improvement Program* by Dr. G. Fred Lee and Dr. Anne Jones-Lee on the fundamental inadequacy of the DEIS/R's analysis of the project's potential adverse impacts to water quality. (Attachment 1)

The DEIS/R failed to address our scoping comments for this project with respect to water quality issues. It does, however, acknowledge that the project will require a Clean Water Act § 401 Certification. Regardless or whether our concerns are adequately addressed in this environmental review, DWR and BOR cannot avoid addressing these issues in what is likely to be a highly contested certification process.

The Delta is identified on the California Clean Water Act 303(d) List as impaired because of diazinon, chlorpyrifos, DDT, Group A Pesticides, electrical conductivity, mercury, organic enrichment/low dissolved oxygen and unknown toxicity. Old and Middle Rivers

are listed as impaired because of low dissolved oxygen. The DEIS/R acknowledges that changes in hydrology can affect fate and transport of pollutants. It also acknowledges that synthetic and natural contaminants have bioaccumulated in Delta fish and other aquatic organisms and that synthetic organic chemicals and heavy metals are found in Delta fish in quantities exceeding acceptable standards for food consumption. Inexplicably, the DEIS/R fails to address the project's effects on the full suite of pollutants presently identified as impairing Delta waters, with the exception of salt. The DEIS/R cannot simply evaluate project impacts in terms of a "conservative" constituent like salt or impacts to dissolved oxygen in the Stockton deep-water channel. It must analyze and quantify the Project's effects on toxicity and impairing constituents in the south Delta and propose mitigation, so that the public and decision makers may reach their own conclusions about the adverse impacts of the project. *Save Our Peninsula v. County of Monterey* (2001) 87 Cal. App. 4th 99, 130. *See Citizens to Preserve the Ojai v. County of Ventura* (1986) 176 Cal. App. 3d 421, 432-33 (finding "an absolute failure to comply [with CEQA]" where information relevant to project's impacts was omitted).

Toxicity to lower tropic populations in Paradise Cut, attributable to organophosphorus insecticides, extends for weeks at a time. Delta waters frequently contain a cocktail of as many as 15 pesticides. Many of these interact additively or synergistically and/or bind to sediment. The tissue of fish collected from the South Delta contains high concentrations of bioaccumulative toxins (i.e., legacy pesticides, mercury and PCBs). Changes in south Delta hydrology will inevitability affect the fate and transport of these toxic constituents. The DEIS/R must be revised to include a characterization and assessment of the sources, mass loading and fate and transport of all pollutants likely to be present in south Delta channels and an evaluation of water quality impacts from the project and alternatives.

There are indications that selenium loads in the San Joaquin River have historically been diverted down Old River. Benthic organisms bio-accumulate selenium. The EIR/EIS should evaluate the effects of redirected selenium loads into the eutrophic areas of the Central Delta.

Dioxin concentrations significantly above levels protective of public health have been documented throughout San Francisco Bay and the Stockton Deep-Water Channel. Discussion with staff from the California Department of Public Health and the Central Valley Regional Water Quality Control Board, as well as private consultants, lead CSPA to believe that elevated concentrations of dioxins are likely present in the South Delta. The SDIP should evaluate the project's effects on likely dioxin concentrations in the South Delta.

Elevated levels of pathogens have been identified in the South Delta. Changes in flow will likely have an effect on concentration and spatial distribution of bacteria, viruses and parasites. Consequently, the DEIS/R must identify and evaluate the project's effects on pathogens.

The project's permanent barriers and inevitable changes in hydrology and export rates will likely have a significant effect on existing efforts to achieve water quality standards.

The DEIS/R must discuss the project's compatibility with TMDLs, Toxic Hot Spot Cleanup Plans, NPDES permitting for increased contaminate loading and Basin Water Quality Control Plans. It must also discuss how altered flow and increased exports will effect implementation of control measures.

Increased exports will likely alter streamflow regimes on major tributaries to the Delta (including the Trinity and Klamath Rivers). The DEIS/R must more completely evaluate and discuss the project's effects on the physical and chemical parameters necessary to support renewable fisheries within upstream tributaries and reservoirs.

Increased exports during certain periods of the year will likely lead to reductions in streamflow during other times of the year (as the VAMP did on the San Joaquin River). This will almost certainly lead to a reduction in assimilative capacity (i.e., reduction in available dilution) on a number of Bay/Delta tributary rivers during certain time-periods. Reduction in streamflow and the resulting loss of assimilative capacity could necessitate more stringent NPDES permit limits. More restrictive permit limits will require dischargers to expend enormous sums of money to comply with new limits. The DEIS/R must evaluate the impacts to dischargers who will face more stringent permit limits caused by reductions in available dilution. Class water present -

A significant SDIP component involves increased dredging of south Delta channels. Recently, the Central Valley Regional Water Quality Control Board strengthened requirements for dredging and dredge spoil placement. A comprehensive assessment of contaminate remobilization from dredging activities and potential effects of land disposal on terrestrial organisms is required. The discussion must include an evaluation of the adequacy of available sediment analyses (i.e., number of core samples, locations, constituents analyzed, concentrations, detection limits, etc.) and identify and evaluate disposal sites.

Lastly, we note that State Water Resource Control Board Revised Water Rights Decision 1641 changes the salinity standard for south Delta channels from 0.7 mmhos/cm (April through August) to 1.0 mmhos/cm upon implementation of the permanent barriers. This degradation of water quality represents a significant adverse environmental impact. The DEIS/R is deficient for not discussing and mitigating this degradation of water quality on south Delta agriculture.

2. The Analysis of Upstream Fisheries Impacts Caused by SDIP Is Inadequate.

The SDIP DEIS/EIR contains unsubstantiated findings about the lack of impacts to Central Valley fisheries. Spring chinook, fall Chinook and steelhead spawn, migrate and hold during periods when temperatures can be an issue in the summer and early fall. The same is true for pelagic species in the Delta. The DEIS/R fails to recognize the importance of steelhead and Chinook in sport, tribal and commercial harvest, and it fails to identify that lower upstream carryover storage will have a negative impact on the survival of Central Valley fisheries below major dams. The DEIS/R completely ignores

the issue of cold water reserves that are required in upstream reservoirs to ensure that adequate stream temperatures can be achieved in the dry periods and parts of each year (summer) in which cold water is most necessary for species survival.

Presumably, increased export rates could lead to drawdown of upstream reservoirs. Should the SDIP lead to reductions in upstream reservoir storage and water elevation, the effects on fisheries and recreation in the affected impoundments requires a much more complete analysis than has been done in the DEIS/R. It should also discuss potential effects to non-state water project facilities and water rights holders (i.e., those having to meet shortfalls induced by the SDIP).

very imp!

The DEIS/R should be revised to include a full analysis of impacts to Central Valley River temperatures from the SDIP-OCAP project and of each alternative's likely consistency with State and federal water quality standards and objectives. The DEIS/R revision should evaluate project compliance with all Delta water quality standards, including the .7 EC standard at interior Delta locations as required by D-1641.

The BOR has previously recognized the need to lower Delta export as a result of a decision limiting diversions from the Trinity to the Sacramento/Delta system. The 2000 Trinity River Record of Decision (ROD) called for increased fishery flows into the Trinity River from Trinity and Lewiston Dams, corresponding to roughly a 1/1 reduction in water exports to the Sacramento River. It is now apparent that the BOR, through the SDIP, has no intention whatsoever of honoring its requirement to reduce water exports to the CVP commensurate with the increase in Trinity River fishery flows. Instead, BOR intends to continue historic deliveries of CVP water from the Delta, as indicated by the numerous CVP long-term contracts such as the San Luis Unit that promise larger future deliveries.

Therefore, approval of the SDIP and implementation of the Joint Point of Diversion whereby the CVP can send its "surplus" water south of the Delta using SWP pumping capacity will surely result in depleted cold water reserves in all upstream Reservoirs at the beginning of the next multi-year drought. The DEIS/R should identify the source of water for increased SDIP exports and disclose and evaluate environmental impacts in the source areas. Whose water are they exporting in this project anyway? ★★★★★

recent Bay Delta decision applies here

3. The DEIS/R Fails to Acknowledge, Address and Mitigate Project Impacts to the Tracy Fish Facility.

The DEIS/R ignores the effects of barrier operation in conjunction with accelerated export pumping on Central Valley Project export facilities. While DWR's pumping facility draws water from Clifton Court Forebay, the BOR relies upon the Old River tidal pool for its water supply. Implementation of the temporary barriers and increased export pumping have caused water stage height in Old River to decline causing head loss at the BOR pumps, especially during low tides. The Tracy Fish Facility is no longer able to operate within design criteria in accordance with the Biological Opinion and export pumping costs have increased. Moving the Grantline Canal barrier further downstream

will further constrict BOR's tidal pool. The proposed project will exacerbate these problems by causing further and longer reductions in stage height, reduced fish salvage effectiveness, greater turbulence and increased electricity costs.

The south Delta has lost 4-5 feet in stage height since the 1950's. BOR staff has suggested that as much as an additional 4 feet head loss could occur in the coming years from implementation of the Intertie (1.5 foot loss), Banks 8,500 cfs (1 foot loss) and Banks 10,200 (1.5 foot loss).

Temporary barriers and increased pumping have reduced primary and secondary channel and holding tank velocities and secondary bypass ratios are now below one. Turbulence has increased. The primary channel was designed to operate at a 16-21 foot depth but now operates at 13-19 foot depth. The secondary channel was designed to operate at a 5-10 foot depth but presently operates at a 0.5-8 foot depth. The holding tank was designed to operate at a minimum depth of 5 feet but now operates at a minimum depth of 0.5 feet. Fish salvage effectiveness has been reduced from design criteria (80-90% in the 1960's) to 50-60% (early 1990's) to less than 20% today. Improving TFCF Hydraulics, Lloyd Hess, Attachment 2.

BOR project pumps are 3 feet lower than DWR's export pumps. Operation of permanent barriers will:

a. Reduce the volume of water available to BOR at low tides.
b. Will cause longer low tides.
c. Increase debris buildup on trash racks.
d. Increase power costs from having to raise water from a lower elevation.
e. Further decrease the efficiency of salvage operations.
f. Increase sedimentation in Old River adjacent to BOR's facility.

The DEIS/R must be withdrawn and revised to analyze and discuss the project's adverse impacts to the BOR facility.

4. The DEIS/R Fails to Adequately Analyze and Mitigate Impacts from New and/or Modified Irrigation Diversions.

Since the project will lower water levels in the south Delta during periods of high export pumping, the project proposes to extend 24 agricultural intakes and install more powerful pumps to facilitate irrigation. These new pumps will replace less powerful pumps or, in many cases, existing siphons and are more likely to entrain fish. However, these new pump intakes will not be screened in violation of California Department of Fish and Game and NOAA Fisheries fish screen policies. This despite clear evidence from DWR's Particle Tracking Model that these diversions are a cause for fish loss in the south Delta. The DEIS/R is deficient for not analyzing and mitigating increased entrainment.

5. The DEIS/R's Analysis and Explanation of the Project's Effects on South Delta Water Circulation and Water Quality is Deficient.

One of the three identified project purposes is to "[m]aintain adequate water levels and, through increased circulation, water quality available for agricultural diversions in the south Delta, downstream of the head of Old River." The DEIS/R describes the modified circulation pattern as:

a. During high tides the three gates will be lowered to allow water to flow upstream. The gates will be raised prior to the following ebb tides to ensure adequate water level remains behind the gates.

b. The height of the Grantline Canal barrier will be lower than the Old River and Middle River barriers and this will ensure that water will flow from Old and Middle River into Grantline Canal to exit over the Grantline barrier.

The Summary of Environmental Effect (Chapter 4, page 4.4) states that construction and operation of permanent gates would not result in any significant reductions in south Delta channel tidal level. This begs the question of what is significant. For example, Figure 4.1 (Minimum and Maximum Tidal Level for Grant Line Canal at Tracy Boulevard Bridge for Each Alternative) reveals that installation of permanent barriers would reduce the tidal level about 0.5 feet (maximum tide) and up to 1.0 feet (minimum tide). Examination of DSM-2 validation (Appendix D-24 – D-26) reveals that model simulations of tidal elevations in south Delta waterways are 0.5 foot to 1.0 foot higher than measured tidal elevations. Clearly, replacement of the temporary barriers with permanent barriers results in lower water elevation in the south Delta.

The DEIS/R doesn't include DSM-2 validation for salinity (EC) for interior south Delta stations. However, DWR's web sit does contain comparisons between current calibration and observed EC levels for interior south Delta stations. http://modeling.water.ca.gov/delta/studies/validation2000/map.html. Both 14-Day Moving Averages and 24.75 Hour Running Averages show substantial differences between simulated and observed EC levels. For example, simulated EC at Old River at Tracy Boulevard is often more than 1,000 μS/cm lower than field observation. Any representation regarding improved EC in the south Delta resulting from implementation of permanent barriers must be taken with a grain of salt. The DEIS/R must be revised to adequately discuss the potential errors in modeling and the relative probabilities of increased circulation, water levels and water quality.

using modeling to lie

The modeling fails to account for resistance in the upper reaches of Old and Middle Rivers, especially during the two low tide cycles each month. As tidal flow pushes upstream, it encounters greater resistance until the net flow disappears and a null zone develops. Resistance can also be increased as channel geometry changes (i.e., increases in sedimentation or formation of sandbars). DWR modeling relies upon old data and, consequently, it is unlikely that the simulations accurately reflect current conditions. It also incorporates an assumed average salinity concentration for local agricultural

discharges despite the fact that central Delta farmers discharge lower levels of salt than south Delta farmers. This has the effect of understating the salinity in return flows and the resulting salinity concentrations in south Delta channels. Further DSM-2 treats waterways as boxes and a comparison of actual channel dimensions with modeled dimensions reveals substantial differences, often as much as 20-25% (personal conversation, Jeff Stuart, NOAA Fisheries). These effects are likely to be exacerbated as agricultural diversions remove water from the channels. It is possible that, under these conditions, there would be no net flow down Grantline Canal. Indeed, considering that the modeling of agricultural diversion is based upon 30-day averages (and farmers don't irrigated on 30-day averages), it is likely that actual agricultural diversions would lead to channel depletion causing reverse flows down Old and Middle Rivers for significant periods. The DEIS/R must be revised to provide a candid in-depth discussion of how circulation will be assured under the project.

There have been several suggestions that the use of low lift pumps would help ameliorate problems cause by lack of circulation. We note that Volume 1, Page 2-23, Gate Design and Construction Detail states that "[p]er a developing agreement with south Delta water users, three agricultural gates may include structural and wiring features that would allow the easy addition of low head pumps and piping, should this contingency prove necessary and appropriate in the future." However, this would raise problems of its own and is clearly outside the scope of the described project. As such, implementation of these structural and wiring features would represent an illegal commitment of resources in violation of CEQA.

Another problem largely ignored in the DEIS/R is that reductions in San Joaquin River flow through the HOR barrier will make it more problematic for farmers along Tom Paine Slough, Paradise Cut and below the HOR barrier to irrigate. Even a brief loss of suction to a siphon would represent significant trouble and cost to a farmer. The description of potential impacts to Tom Paine Slough, Paradise Cut and upper Old River is seriously deficient and must be revised.

Nor does the DEIS/R adequately discuss the quality of agricultural discharges and return flows and discharges of stormwater and wastewater from municipalities. Considering the rapid growth and increased pollutant loading from Tracy, Mountain House and adjacent communities, it is likely that water quality problems will be exacerbated during periods of low flow or stagnation. The DEIS/R must analyze the effects of these pollutant inputs on water quality.

6. The DEIS/R Ignores Impacts to Aquatic Life from Construction and Operation of Permanent Barriers.

Although DFG trawls are no longer conducted in south Delta channels, these waterways once provided good habitat for Delta smelt. Oddly, there is no analysis of the impacts to aquatic life, including Delta smelt, in south Delta channels although the construction and operation of the permanent barriers and other structural components are likely to have

adverse impacts. The DEIS/R must be revised to include a rigorous discussion of potential impacts to all life stages of all aquatic life in these waterways.

7. The DEIS/R Fails to Analyze the Impacts of Increased Winter Pumping on Delta Smelt.

As previously noted, the decline of pelagic species in the Delta has occurred during periods of increased export pumping and operation of the EWC. In fact, IEP studies have suggested that increased winter pumping is a contributing factor to recent declines of Delta smelt. Since the DEIR/S relies upon EWC, it must analyze and mitigate for adverse impacts to Delta smelt and other species caused by increase EWC winter pumping.

8. The DEIS/R Fails to Analyze Redirected Impacts from SDIP.

The scoping document for the SDIP identified the primary issues as: 1) current and proposed diversion rates impede the ability to divert irrigation water, 2) salinity standards, and 3) decline in Delta smelt and San Joaquin River salmon populations. The project's elements are defined as: 1) increased maximum export capacity at Clifton Court Forebay, 2) dredging in Old River to facilitate increased exports, 3) improved agricultural water delivery by construction of permanent operable barriers and local channel dredging, and 4) construction of a fish control structure at the head of Old River to reduce salmon losses at CVP and SWP export facilities.

However, increased export rates, the potential for increases in total export quantity and the inevitable altered hydrographs on numerous tributaries are likely to affect the entire Central Valley circulatory system. Many of the Delta's present problems derive from a failure to consider the redirected or system-wide impacts caused by previous projects. The DEIS/R must reevaluate the project's potential present and future redirected adverse impacts on: 1) the suite of water quality problems and pollutants in the Delta, downstream waters (Suisun and San Francisco Bays) and upstream tributaries (including the Trinity-Klamath system), 2) aquatic life populations in those waterbodies and 3) existing programs to meet water quality standards (i.e., TMDLs, Toxic Hot Spot cleanup programs, NPDES permits, etc.).

VII. The DEIS/R Fails to Adequately Analyze Cumulative Impacts Caused by the SDIP and Other On-going State and Federal Programs.

NEPA does not allow projects to be analyzed in artificial isolation. Instead, it requires discussion, in an EA or EIS, of the cumulative impacts of the proposed project in combination with "past, present, and reasonably foreseeable future actions." 40 C.F.R. § 1508.7; *see Native Ecosystems Council v. Dombeck*, 304 F.3d 886, 895-96 (9th Cir. 2002). That discussion cannot be "perfunctory," *Kern v. United States BLM*, 284 F.3d 1062, 1075 (9th Cir. 2002), but instead must provide "some quantified or detailed information; ... general statements about 'possible' effects and 'some risk' do not constitute a 'hard look' absent a justification regarding why more definitive information

← CEQA as well I believe

could not be provided." *Id.* (quoting *Neighbors of Cuddy Mt. v. United States Forest Serv.*, 137 F.3d 1372, 1379-80 (9th Cir. 1998)). See also *Muckleshoot Indian Tribe v. United States Forest Serv.*, 177 F.3d 800, 811-12 (9th Cir. 1999); *City of Carmel-by-the-Sea v. United States DOT*, 123 F.3d 1142, 1161 (9th Cir.1997); *LaFlamme v. FERC*, 852 F.2d 389, 401-02 (9th Cir. 1988). CEQA similarly requires lead agencies to consider cumulative impacts, or the incremental effects of the proposed project viewed together with the effects of past, current, and probable future projects. Pub. Resources Code § 21083(b); CEQA Guidelines § 15130(a)-(b).

yes

A cumulative impacts analysis must address "reasonably foreseeable" projects that may have a "synergistic environmental effect" combined with the project under review. *Tenakee Springs*, 915 F.2d at 1312-13. A project is "reasonably foreseeable" when formally proposed by government agencies. *Kern*, 284 F.3d at 1075-78; *Muckleshoot Indian Tribe*, 177 F.3d at 811-12. The state and federal government are required to evaluate their SDIP project in context of the numerous other projects presently contemplated during the thirty-year CalFed program.

Such analysis was particularly necessary here, for the SDIP is a component of a larger set of interrelated actions in the CALFED program, many of which involve sustaining damaging level of exports or increasing extraction of water from the Bay-Delta. In their CALFED programmatic FEIS/EIR, the Bureau and DWR described the SDIP project as part of a broader effort to increase water supply, and the CALFED agencies "recognized that many of their proposed actions were interrelated." BOR EA/IS for the Interte, at 3-86. Likewise, in the OCAP ESA consultation process, the Bureau, FWS, and NMFS defined the SDIP, along with several other changes to CVP and SWP operations, as part of the same overall OCAP project. Cumulative impacts discussions cannot merely provide "general statements about possible effects." *Kern*, 284 F.3d at 1075; *see Neighbors of Cuddy Mt.*, 137 F.3d at 1379-80. Yet the SDIP DEIS/R cumulative impacts discussion contains only generalities and unsupported conclusions in violation of both CEQA and NEPA.

great!

yes

Even if it had prepared the cumulative impacts analysis NEPA requires, the Bureau and DWR could not have explained their deviation from the earlier CALFED EIS/EIR's conclusions, for those conclusions were right. As the CALFED EIS/EIR explained, the SDIP and related projects also designed to sustain or increase exports have significant potential impacts:

1. Export pumping causes "negative" flows, in which water flows toward the south Delta pumps rather than San Francisco Bay, for many months each year. Those "[r]everse flows…have contributed to the reduction of Bay-Delta productivity and of some Bay-Delta invertebrate and fish populations." *Id.* at 6.1-8, 6.1-42 (listing affected species, many of which are threatened or endangered);

2. Export pumping pulls saline water into the Delta. "Sea-water intrusion into the Delta can be intensified by diversion of fresh water and the corresponding decrease of freshwater outflow from the Delta" *Id.* at 5.2-5;

3. Export pumping causes "salinity [that] adversely affects most beneficial uses. Bromides associated with sea water lead to the formation of DBPs in treated water." *Id.* at 5.3-11. Salinity intrusion also forces open water species that prefer non-saline habitat to move from Suisun Bay, which provides open-water habitat, into the Delta, which does not. *Id.*; *see id.* at 6.1-35 (explaining benefits of minimizing saline intrusion);

4. Export pumping kills thousands of fish. Those fish die through "direct loss at pumps, reduced survival when young fish are drawn out of river channels into the Delta, and reduced spawning success of adults when migratory cues are altered." Therefore, "most species are potentially affected" by pumping increases, "including chinook salmon, delta smelt, steelhead, and striped bass"—all of which are protected under federal law;

5. Export pumping for irrigating the west side of the San Joaquin Valley, where SDIP water will be transported, drains pollutants into the San Joaquin River and the Bay-Delta. *Id.* at 5.3-7. The CALFED Program EIS/R recognized that "Inadequate natural drainage, salt accumulation, and high selenium concentrations in agricultural return flow have been long-standing problems in this area and have intensified with the importation of irrigation water from the Delta." *Id.* at 6.1-11; and,

our Bay Delta case

6. Export pumping threatens compliance with federal and state law, both of which require attaining water quality objectives and recovering endangered species populations. CALFED specifically acknowledged that "[t]here is concern whether a through-Delta conveyance approach," in which water is sucked through the Bay-Delta by the South Delta pumps, "can meet future water quality objectives and not adversely affect the recovery of threatened and endangered fish species." *Id.* at ES-17.

The CALFED EIR analysis confirms a common-sense notion: increasing the already-massive amount of water pumped out of a fragile aquatic ecosystem, at a time when other export-increasing projects are proposed, fish populations in that ecosystem are threatened or collapsing, and water quality already fails to meet federal and state standards, is likely to cause adverse environmental impacts. The SDIP DEIS/R's contrary conclusion is arbitrary and unreasonable given the historical facts in the Bay/Delta.

Further, the DEIS/R fails to identify and analyze a number of other existing and proposed projects that will have synergistic environmental impacts. Consequently, the DEIS/R is deficient, and should be withdrawn and revised to address and analyze these projects.

1. **South Delta Temporary Barriers Project.** The DEIS/R begins with the clear assumption, that project effects from the Temporary Barriers project are part of the "baseline." As such they are not to be considered impacts of this project. However, a careful review of the environmental documentation for the Temporary Barriers project clearly identifies areas of concern that were to be studied. Examples include the effects of inundation of listed plants (such as the Mason's lileaopsis), by the operation of the barriers, and the accumulation of avian and fish predators at the barrier sites. These impacts have occurred and are the responsibility of the Temporary Barrier's Project to mitigate. Since the SDIP will replace the Temporary Barrier's Project, it becomes the responsibility of the SDIP to mitigate for these impacts.

2. **City of Stockton Drinking Water Intake.** The City of Stockton is planning to construct an intake on the San Joaquin River near Potato Slough. The environmental documents for the project acknowledge entrainment and reduction of Delta outflow issues.

SDIP, Intertie, Peripheral Canal + increase exports

3. **Delta Improvement Project (DIP).** This CalFed program includes the SDIP, the Delta Cross-channel re-operation, the Through Delta Facility, the Frank's Tract modification, the Contra Costa Water District facilities, and the increases in export capability.

4. **CVP-SWP Intertie.** A connection between the CVP's Delta Mendota Canal and the SWP's California Aqueduct, which will permit 300 cfs to be pumped from the CVP to the SWP, and will allow up to 900 cfs to flow from the SWP to the CVP.

5. **Joint Point of Diversion and Coordinated Operating Agreement.** This item is currently before the SWRCB, who is currently conducting a Cease and Desist Order hearing on the subject of violations of internal Delta water quality standards by the CVP and SWP.

yes

6. **Port of Stockton Water Quality Improvement Project.** This project proposes to inject oxygen into the zone of low DO in an effort to improve the water quality. Injection of pure oxygen into the water column is likely to create super saturated conditions detrimental to fish.

7. **San Joaquin River Recirculation** – This proposed recirculation program would move Delta water south, via the Delta-Mendota Canal, to the Newman Wasteway for release into the San Joaquin River.

NEPA also does not allow project to be analyzed in artificial isolation. Instead, it requires discussion of the cumulative impacts of the proposed project in combination with "**past**, present and reasonably foreseeable future actions." The past direct and indirect impacts to the aquatic habitat, ecology and fishery populations from state and

federal project operations (including temporary barriers) have resulted in long-term cumulative adverse effects on present and future generations of aquatic life in the Delta. The DEIS/R is deficient for not candidly discussing project impacts on population trends for striped bass, sturgeon, American shad, Delta and long-fin smelt and other Delta species, including their food webs. Such an evaluation would encompass entrainment of all species of fish and lower tropic populations and provide an assessment of what cumulative impacts have occurred over the life of the projects and what can reasonably be expected to occur if the proposed project goes forward.

VIII. The DEIS/R Improperly Relies on DSM-2 and CALSIM II, Flawed Analytical Tools that Fail to Adequately disclose the SDIP's Environmental Impacts.

The DEIS/R's analyses of water availability, environmental impacts, export and project effectiveness are predicated almost entirely on modeling output. While DSM-2 and CalSim-II may be useful tools, a complete dependence upon modeling is inappropriate as the models are incapable of providing the certainty that is required of an environmental document. Yet, throughout the DEIR/S, modeled predictions are presented as fact. There are no error bars that would indicate the range of uncertainty or accuracy (although the DEIS/R briefly admits that modeled surface elevations in the south Delta tend to be half a foot higher than actual levels). It is simply inappropriate to base major planning decisions on modeling output without discussing model resolution and probabilistic error rates.

DSM-2 has never been peer reviewed and been heavily criticized. It's 2001 calibration and verification report has never been finalized and remains in an incomplete draft form. For example, DSM-2's salinity transport module is one-dimensional and has been calibrated exclusively using surface salinity. It ignores stratification and assumes that surface salinity over a channel cross-section is constant. Only a three-dimensional model can account for higher concentrations of salinity at depth, as has been documented by subsurface monitoring. Examination of the most recent verification of DSM-2 water quality modeling reveals substantial differences between actual and predicted values. For example, as previously discussed, salinity at Old River at Tracy Road 14 Day Moving Averages and 24.75 Hour Running Average Plots: 1 April 1900 through 30 September 1994 and 1 October 1994 through 30 September 1999 show substantial discrepancies; often more than 1,000 μS/cm. http://modeling.water.ca.gov/delta/studies/validation2000/qual-ec/rold059Avg.html. It is clear that any claimed improvement from the project implementation is lost within the "noise" of the model. Consequently, proponent claims that the project will improve electric conductivity by a precise amount are without creditable foundation.

CALSIM II modeling is similarly flawed. CalSim II is not an accurate model design to evaluate environmental impacts of the SDIP-OCAP and it has not been sufficiently calibrated for this use. DWR and BOR have been told this by other scientists repeatedly. CalSim-II is being used in every significant water planning process now underway in California. When the outcome of a planning process like this one hinges on modeling

results, even partially, the assumptions and assertions that lead to these results should be accurate and transparent. Indeed, the failure to utilize an accurate model to assess the environmental impacts renders the DEIS/R's analysis inadequate. *See Berkeley Keep Jets Over the Bay v. Board of Port Commissioners,* 91 Cal. App. 4th 1344 (2001) (finding that agency improperly relied on outdated air quality model to assess the impact of toxic air contaminants.)

Given the paucity of available empirical water quality data, evaluations of project impacts on water quality and flow are dependent upon flow and water quality modeling efforts. However, hydrodynamic modeling by any known technique is not an exact science. Models are easily manipulated and should not be employed as substitute for hard data or common sense. Subtle changes in coefficients or assumptions can dramatically alter output. Input variables are critical. Proper calibration and verification is crucial. Even then, models are only an idealization of actual field conditions and must be used with caution to ensure that underlying assumptions hold for the site-specific situation being modeled. For example, the DEIS/R's assumption that future water flow patterns will be similar to those that have occurred in the past is clearly inconsistent with the body of literature on the effects of global warming on California water flows. The use of average values in modeling ensures results that are generally unprotective of specific water quality criteria. Virtually all models, even those subject to peer-review, have significant rates-of-error, often greater than plus or minus 50%.

The DEIS/R fails to identify and discuss:

1. Model input variables; i.e., channel geometry, surface and bottom temperature and density, constituent concentration, velocity, friction factors, stratification, etc.
2. Calibration and verification of models; i.e., adequacy of baseline data for various constituents and how closely output conforms to actual field measurement.
3. Assumptions used in modeling flow and water quality. For example, CalSim II studies for the SDIP have assumed that Stanislaus River operations are in accordance with the USBR's New Melones' Interim Operation Plan. However, since the Interim Operation Plan cannot be met during drought cycles, the model cannot accommodate the lack of New Melones' storage and reduced instream flow during consecutive drought years.
4. Foreseeable future changes: i.e., loss of storage capacity due to sedimentation and the continuing 80 year decline in snowmelt as a percentage of yearly runoff.

The independent peer-review report titled *A Strategic Review of CALSIM II and its Use for Water Planning, Management, and Operations in Central California* that was submitted to the California Bay Delta Authority Science Program in December 2003 documented numerous problems with the model. (Attachment 6) The report stated that "[I]n our opinion CalSim II has not yet been calibrated or validated for making absolute predictions values. Report at 6.1, absolute Values or Comparative Results. It further stated that the panel is skeptical of the suggestion that, while the model might not

generate a highly reliable absolute prediction because of errors in model specification and /or estimation, it might produce a reasonably reliable estimate of the relative change in outcome.

Among the many weaknesses noted by the peer-review panel are:

1. The model is too complex and did not handle particular components of the system with sufficient detail.
2. The model provides limited and inadequate coverage of non CVP or SWP water and of the California water system south of the Delta.
3. The model assumes that facilities, land-use, water supply contracts and regulatory requirements are constant over this period, representing a fixed level of development rather than one that varies in response to hydrologic conditions or changes over time.
4. Groundwater has only limited representation in CalSim II.
5. Groundwater resources are assumed infinite, i.e., there is no upper limit to groundwater pumping.
6. The linear programming model considers only the current month, and hence CalSim II operating rules are required to determine annual water allocations, to establish reservoir carryover storage targets, and to trigger transfers from north of Delta to south of Delta storage.
7. Better quality control is needed both for the model and its current version and input data. Procedures for model calibration and verification are also needed. Currently many users are not sure of the accuracy of the results. A sensitivity and uncertainty prediction capability and analysis is needed.
8. Need improved ways of altering the model's geographic scope and resolution and its temporal resolution to better meet the needs of various analyses and studies.
9. Need to improve the model's comparative as well as absolute (or predictive) capabilities.
10. CalSim II needs better capabilities for analyzing economic, water quality, and groundwater issues.
11. Need improved documentation explaining how the model works, its assumptions, its limitation, and its applicability to various planning and management issues.
12. DWR and USBR have not provided a centralized source of support for CalSim II. More training for CalSim II is needed. There is a need for more people who can run CalSim II. There is a need for a well-publicized user group. A more extensive users' guide is needed.
13. Improved capabilities are needed for real-time operations especially during droughts, gaming involving stakeholders during a simulations run, handling of evapotranspiration and agriculture demand changes over time, water transfers, Delta storage, carryover contract rights, refuge water demands and more up to date representation of Feather River, Stanislaus River, Upper American River, San Joaquin River and Yuba River operations.
14. Need an improved graphical user interface to facilitate input of model data, setting of model constraints and weights, operating the model, and displaying and post analysis of model results.
15. Need to be able to change the model time period durations for improved accuracy of model results.

Many of the above-enumerated weaknesses of CalSim II were also identified in the

survey report from the University of California at Davis. Ferreira, et al. 2003. Additional flaws in the statistical basis for CalSim II was revealed in a recent study titled *Analysis of CALSIM's Statistical Basis* by Arve Sjovold, 28 December 2005.

Additionally, an expert panel sponsored by the CalFed Science Program and the California Water and Environmental Modeling Forum recently reviewed the CalSim II model representation of the San Joaquin River. http://science.calwater.ca.gov/workshop/calsim_05.shtml. The January 2006 report titled *Review Panel Report San Joaquin River Valley CalSim II Model Review* found that the model:

get this officed!

1. Used incomplete data sets.
2. Underestimated salinity.
3. Underestimated releases of water from New Melones Reservoir that leads to overestimates of water availability to entities dependent on New Melones storage.
4. Documentation and testing was not sufficient to provide users or model results with a complete reasonable basis for understanding the accuracy and limitations of results.
5. Did not include groundwater.
6. Took loss and return flow rates from older model without re-examination and scrutiny.
7. Failed to update Westside water demands.
8. Failed to include error rates.

Since the San Joaquin River module sets boundary conditions for the Delta, errors are likely to be carried over to the rest of CalSim II's output.

Another recent critique of CalSim II titled *An Environmental Review of CalSim-II, Defining "Full Environmental Compliance" and "Environmentally Preferred" Formulations of the CalSim-II Model* by Jeffrey T. Payne and Dr. David R. Purkey of the National Heritage Institute, November 2005, (Attachment 7) was prepared in order to examine the transparency of CalSim-II and to measure the current version of the model against two important standards. This report is purposely focused on two specific questions.

1. Does the representation of environmental regulations and objectives in CalSim-II represent full compliance with current legal requirements?
2. Can CalSim-II be used to plan for water management alternatives associated with improve environmental outcomes and habitat restoration?

The NHI report does not deal with any of the other CalSim-II issues identified in the CalSim-II Peer Review. All of the issues identified in the review cause flaws in the results displayed in the SDIP EIR/S. The Natural Heritage Institute (NHI) was hired to carry out the technical analysis needed to determine whether CalSim II can answer the above questions. The first question was posed in order to assure that the current

formulation of CalSim-II is consistent with all current environmental regulations on California's water resources.

CalSim-II attempts to characterize all components of the regulatory structure. This report reviewed a significant but limited subset of these regulations. Those reviewed were selected based on the experience of a panel of environmental experts. This selection does not imply that characterizations of other regulations in CalSim-II meet the full compliance standard. In fact, it would be very valuable for the SDIP proponents to complete a similar analysis on the model characterization of all existing environmental regulations. With regards to the Full Compliance standard, NHI identified three areas where the assumptions and assertions in the current version of CalSim-II were at odds with the expert panel's interpretations of existing environmental regulations:

- **CalSim-II uses information not available to real time operators of the California water system.** This allows CalSim-II to relax environmental standards earlier than is the case in actual operations. As a result, the model under-allocates water needed to satisfy existing environmental regulations; in turn, the model makes that water available for export to south of Delta contractors or other uses.
- **CalSim-II is not faithful to Federal law that allocates water to meet ecosystem restoration objectives.** The 1992 Central Valley Project Improvement Act calls for 800 TAF of water to be allocated for environmental regulation and the logic of CalSim-II does not fully honor this requirement.
- **CalSim-II currently includes no requirement to maintain a minimum flow in the San Joaquin River below Friant Dam**, contrary to a court ruling requiring such flows. This allows for allocation of water to urban and agricultural uses in the Friant Service area rather than allocating that water to maintain water in the San Joaquin River.

For each of these deficiencies, this report proposes a series of actions that can be taken in order to improve the performance of the model. These should be considered the minimum steps required to meet the Full Compliance standard for the regulations reviewed as part of this effort.

The second question is motivated by the SDIP proponent's historic failure to protect and restore the Sacramento-San Joaquin watershed as legally required. Long-term monitoring of the system suggests that threatened and endangered fish populations are in serious jeopardy. A prudent approach to water management planning would use modeling tools that evaluate the impact of various environmental regulations on water deliveries. CalSim-II has not been crafted to include this flexibility.

As examples of the kinds of new regulations that may need to be considered before CalSim-II can be adequately used in SDIP, the expert panel identified the following regulatory changes that the model needs:

- CalSim-II should have the flexibility to shift salinity compliance points to allow more targeted tributary restoration action. For example, changing the location of the Vernalis salinity standard may reduce the burden on the Stanislaus River.
- CalSim-II should have the capacity to shift required salinity profiles in the Delta (X2) to benefit Delta-dependent species.
- CalSim-II should allow for the prioritization of tributary environmental objectives, such as targeted operation of the Nimbus/Folsom system for the American River.
- CalSim-II should allow for the modification of Delta export restrictions to target improvements in the Delta ecosystem.
- CalSim-II should not count, towards the satisfaction of environmental regulations, water that otherwise would have been released as part of unavoidable reservoir spills.
- CalSim-II should allow for the definition of flow requirements that result in periods of spring high-flow and summer low-flow conditions in Central Valley rivers.

These changes are consistent with the need to comply with existing environmental laws (CEQA, NEPA, ESA) through the evaluation of alternatives, including identifying those that are the most environmentally beneficial. Given the historic difficulty associated with returning the San Francisco Bay/Delta to a viable ecosystem, these changes would allow policy makers to engage in more thoughtful alternatives analysis.

Having completed this environmental review of the CalSim-II model the authors of the attached review say, "we are left with the profound impression that it is not a tool that can – under its current formulation – fully address the legally required water management objectives. CalSim-II is, after all, a tool that has been designed to determine how best to operate the state's hydraulic infrastructure in ways that maximize the satisfaction of contractual demands. This reality is a result of both the history of water model development in California and a general analytical approach that has held sway for decades in the field of water resources planning and analysis. This approach holds that the environment is a constraint on system operations, not one of the objectives for which the system should be managed. In order to create a tool that can investigate water management innovations designed to comply with the law and restore the environment, it is not simply a matter of adjusting a few input parameters. Instead, a reformulation of the model along the lines described in this document is needed."

This philosophy of including the environment as an objective in water resources management is gaining credence around the world. Unfortunately, in California we cannot get to this point if we limit ourselves to the current version of CalSim-II. In any event, CalSim II is an inadequate tool for SDIP alternatives analysis as it cannot be adjusted to solve for improved environmental conditions; it can only tell us how to maximize exports. In other words, CalSim II cannot measure environmental impact above baseline standards; it can only measure the impact of improving the environment on water export amounts. Project proponents have also improperly employed CalSim II results to represent precise predictions regarding potential impacts although it has not yet

been calibrated or validated for making absolute predictions values. That is not acceptable NEPA/CEQA environmental analysis.

Finally, we note that the U.S. District Court for the Northern District of California recently issued a Temporary Restraining Order in an action brought by the Planning and Conservation League against the BOR enjoining construction of the Intertie because, in part, the BOR failed to disclose the short-comings of the data or models. Here, the DEIS/R for the SDIP also fails to disclose error-bars and numerous other limitations in the modeling. The DEIS/R also inappropriately uses the model for predictive rather than comparative purposes, especially in addressing whether the project would meet specific water quality standards, maintain specific tidal levels, etc.

IX. The DEIS/R's Mitigation for Project Impact is Inadequate and Fails to Comport with Legal Requirements.

As the California Supreme Court has repeatedly emphasized, "the chief goal of CEQA is mitigation or avoidance of environmental harm." Laurel Heights I, 47 Cal.3d at 403; see Goleta II, 52 Cal.3d at 564. CEQA requires public agencies such as the County to implement this goal through a three-step process. First, the County must accurately identify, analyze, and disclose the adverse impacts of a Project. Stanislaus Natural Heritage Project v. County of Stanislaus (1996) 48 Cal.App.4th 182, 196-97. Second, the County must "identify mitigation measures for each significant environmental effect." Guidelines § 15126.4(a)(1)(A). Finally, the County must actually adopt such mitigation measures, unless it is infeasible to do so. § 21002.1(b) ("Each public agency shall mitigate or avoid the significant effects on the environment of projects that it carries out or approves whenever it is feasible to do so."); Citizens for Quality Growth v. City of Mt. Shasta (1988) 198 Cal.App.3d 433, 440-41.

"Mitigation" as defined in CEQA includes:

1. Avoiding the impact altogether by not taking a certain action or parts of an action.
2. Minimizing impacts by limiting the degree or magnitude of the action and its implementation.
3. Rectifying the impact by repairing, rehabilitating, or restoring the impacted environment.
4. Reducing or eliminating the impact over time by preservation and maintenance operations during the life of the action.
5. Compensating for the impact by replacing or providing substitute resources or environments

CEQA Guidelines section 15370. This definition of the term "mitigation" adopts the definition contained in the federal NEPA regulations. The federal definition is used so that this term will have identical meanings under NEPA and CEQA for projects that are subject to both acts.

The DEIS/EIR proposes a novel set of "Mitigation Measures" for the impacts associated with the proposed actions. As discussed below, these actions will not reduce or avoid significant project impacts, but instead seem to totally rely upon the Environmental Water Account (EWA) and fail to meet the requirements of either NEPA or CEQA, as they are contingent on other actions outside the scope of, and beyond the control of, this project.

This deficiency is clearly evident in the text taken from page 6.1-2 of the DEIS/EIR:

1. *Avoidance Measure.* All pumping at SWP Banks that is in excess of the existing permitted capacity from November 1 through June 30 will be tracked by EWA and SWP/CVP operations staff. When EWA actions reduce exports for fish protection during this period, any pumping at SWP Banks that is above the existing permitted capacity will be reduced without cost to the EWA account, limited only by the amount of pumping reduction funded by the EWA (i.e., maximum of 100% match with EWA action).

This suggests that the proponents agree not to use the excess "Banks" pumping plant capacity to pump above the existing permitted capacity, only if, and limited by the size of, the EWA actions at that time. However, it would appear to reserve the right to exceed the permitted capacity, if any remained, after the EWA action was taken into account.

In other words, the project proposes to exceed the "existing permitted export capacity" when it suits them. Clearly this is not mitigation for project impacts, but would in fact exceed the limits of the EWA, the very measure the project relies upon to reduce project impacts.

2. *Crediting Measure.* From November 1 through March 31, pumping reduction credits will be given to the EWA (ranging from 10% to up to 30%) for all non-EWA pumping that is above the existing permitted capacity. Under this mitigation component, for each 100 taf of non-EWA pumping above the existing permitted capacity, a pumping reduction credit, ranging from 10 taf to 30 taf, could be used by EWA to reduce pumping during periods of high fish density.

This measure appears to offer a 1:10 (or a 3:10) exchange for non-EWA pumping above the existing permitted capacity, between November 1 and March 31. Again, the project proposes to permit "non-EWA pumping above the existing permitted capacity" as it suits them.

The limitation of actions to mitigate for losses that may occur during the May 16 to May 31 pumping, which is subject to actions by the EWA, is not mitigation. There is no certainty to the proposed mitigation and it is subject to an action that is unrelated to this project. As such, it has not met the test of mitigation, since it is not available without other independent actions. Further, the decision maker cannot with any certainty

determine the level of mitigation being proposed, since the nature of the external actions cannot be determined.

EWA may not even be real it has no secure funding to carry it out.

Given the definition from CEQA, it is difficult to see how the various proposed mitigation measures in the DEIS/R are valid. For example, "Mitigation Measure Fish–MM–1 " is premised on another action by an unrelated event i.e., the actions of the EWA. Nowhere in the definition is the mitigation, of acknowledged impacts, made subject to contingencies based on an unrelated event. The DEIS/R also fails to make provision for mitigation in the event EWA actions are not taken to reduce entrainment. As a result, MM-1 relies entirely on an existing program, the EWA, to mitigate new impacts associated with the SDP. The EWA has already proven unsuccessful at protecting aquatic species in the Delta. This existing program cannot satisfy the requirement that impacts associated with the SDIP be mitigated, especially since EWA winter pumping has been targeted by the IEP POD studies as a potential cause of the loss of Delta smelt in the winter. Finally, studies (or initiatives) are not mitigation.

Mitigation Measure Fish-MM-3: Minimize Entrainment Losses of Delta Smelt Associated with Increased SWP Pumping (Volume 1 – Page 6.1-96) states that "[t]he SWP has proposed increased funding through an amended Four-Pumps Agreement to support SDIP mitigation measures, including an expanded EWA. In the absence of the EWA, that increased funding would continue to be available to DFG to mitigate impacts of the SDIP through purchases of water to reduce pumping during critical periods for fish or other mitigation strategies developed through the adaptive management process." The funds in the Four-Pumps Agreement are mitigation for on-going losses of fish the result of the existing operations of the SWP. Why would those funds be used to then permit additional damage? Those funds are (or should be) fully encumbered for existing loss mitigation. It is the worst form of chicanery to propose the use of these funds to permit the projects to increase their impacts on the populations of fish we are trying to preserve.

why should DFG have to "purchase" water?

Impact Fish-68: Operations-Related Increases in Entrainment Losses of Splittail (Volume 1 – Page 6.1-99) acknowledges spawning on the San Joaquin River, and an increase of up to 40% in entrainment (10 to 20% in other years), but concludes that no mitigation for these increases is warranted due to the Sacramento River production, and the fact that they occur in the drier years. The loss is acknowledged, the impacts can be avoided or minimized, and the mitigation is feasible but proponents simply decided that they just don't want to do it. This is unacceptable and in violation of CEQA and NEPA.

The bottom line is that the DEIS/R relies upon the EWA for mitigation despite the complete lack of credible studies documenting the success of the EWA in reducing adverse impacts from water exports. Indeed, the decline in Delta fish species has occurred and accelerated concurrent with increased exports and operation of the temporary barriers. As an added insult, the DEIS/R states that mitigation measures would be carried out "if necessary." The DEIS/R must clearly define precise mitigation measures that will be established and the specific assurances that will ensure that the mitigation measures will be successfully implemented.

Thank you for considering these comments. Please place us on all lists to receive the FEIS/R, notice of hearing dates and the Notice of Determination. We reiterate our request that the comment period be extended another 30 days in order to allow sufficient time to review and analyze the 2,788 pages of this document.

Sincerely,

Bill Jennings
Chairman & Executive Director
California Sportfishing Protection Alliance

CSPA SDIP Comments Attachment 1

Comments on

Draft Environmental Impact Statement Environmental Impact Report
South Delta Improvement Program

Prepared by

Bureau of Reclamation for the U .S. Department of the Interior and the Department of Water Resources for the State of California Resources Agency'

Submitted by

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The Department of Water Resources (DWR)/US Bureau of Reclamation (USBR) (DWR/USBR, 2005) draft EIS/EIR states,

> *"The general purposes of the SDIP were identified by the Agencies, as follows:*
>
> *(c) increase water deliveries and delivery reliability for State Water Project (SWP) and Central Valley Project (CVP) water contractors south of the Delta and provide opportunities to convey water for fish and wildlife refuge purposes by increasing the maximum permitted level of diversion through the existing intake gates at Clifton Court Forebay from 6,680 to 8,500 cubic feet per second.*

Basically, in this draft EIS/EIR DWR/USBR have attempted to justify increasing the amount of South Delta water exported by the Central Valley Project (CVP) and State Water Project (SWP).

The Draft EIS/EIR further states,

> *"The impact assessment focuses on benefits and impacts to hydrology, water quality, fish resources, recreation, vegetation and wildlife, ..."*

We are familiar with current water quality issues in the South Delta and the generally inadequate understanding of how the current South Delta water exports through the CVP and SWP impact Delta water quality. **We find that the draft EIS/EIR for the proposed expanded export of South Delta water is significantly deficient in providing an adequate, reliable discussion of the potential water quality impacts of the proposed project.**

At the time of the notice of preparation of this EIR/EIR we were highly involved in a study of the low dissolved oxygen (DO) problem in the San Joaquin River (SJR) Deep Water Ship Channel (DWSC). We were the coordinating principal investigators for a $2-million CALFED-supported study of the characteristics of the low DO problem, factors

influencing the DO in the DWSC, the sources of the oxygen demand, and potential approaches for controlling the concentrations of DO in the DWSC to eliminate violations of the DO water quality objective (WQO). It was through those studies that we found that the CVP and SWP exports of South Delta water were a major factor contributing to the low-DO problem in the SJR DWSC.

We developed a SJR DWSC low-DO "Issues report" for the SJR DWSC TMDL Steering Committee that identified and described many of the issues that needed to be addressed as part of studying the nature of the DWSC low DO problem (Lee and Jones-Lee, 2000). We also developed a Synthesis Report summarizing and integrating the results of the approximately $4-million of studies conducted by about a dozen investigators on the DWSC low-DO problem (Lee and Jones-Lee, 2003a). That synthesis report also presented our findings on the impact of SJR flow in the DWSC on DO depletion below the WQO. Of particular importance were the results of the DWR D-1641 SJR cruises, in which DO was measured at about biweekly intervals from late summer to early winter at the Rough and Ready Island DO monitoring station, and the USGS monitoring of SJR DWSC flow. Lee and Jones-Lee (2003a) reported that when the SJR DWSC flows were on the order of a few hundred cfs, severe low-DO problems occurred in the DWSC. However, when the SJR DWSC flows were above about 1,500 cfs there were no DO WQO violations in the DWSC.

Since completion of the synthesis report we have continued to examine the relationship between SJR DWSC flow and DO WQO violations, and have issued a series of reports of our findings (Lee 2003a, b, 2005a,b; Lee and Jones-Lee 2003a,b,c; 2004a; 2005a,b,c). Those follow-up studies have confirmed that low SJR DWSC flow is a major factor contributing to violations of the DO WQO in the DWSC. It has also been noted that the export of South Delta water through the USBR CVP and DWR SWP is the primary cause of low SJR flow in the DWSC. Basically those projects at times, draw most of the SJR Vernalis water into the South Delta through the Head of Old River to the CVP and SWP export pumps. Figure 1 presents a map of the Delta area of concern in the Delta Improvement Package.

When the SDIP request for comments on the CEQA scope was issued, it was with this background that Lee (2002) submitted comments on the water quality issues that needed to be addressed in the EIS/EIR. Lee (2002) stated,

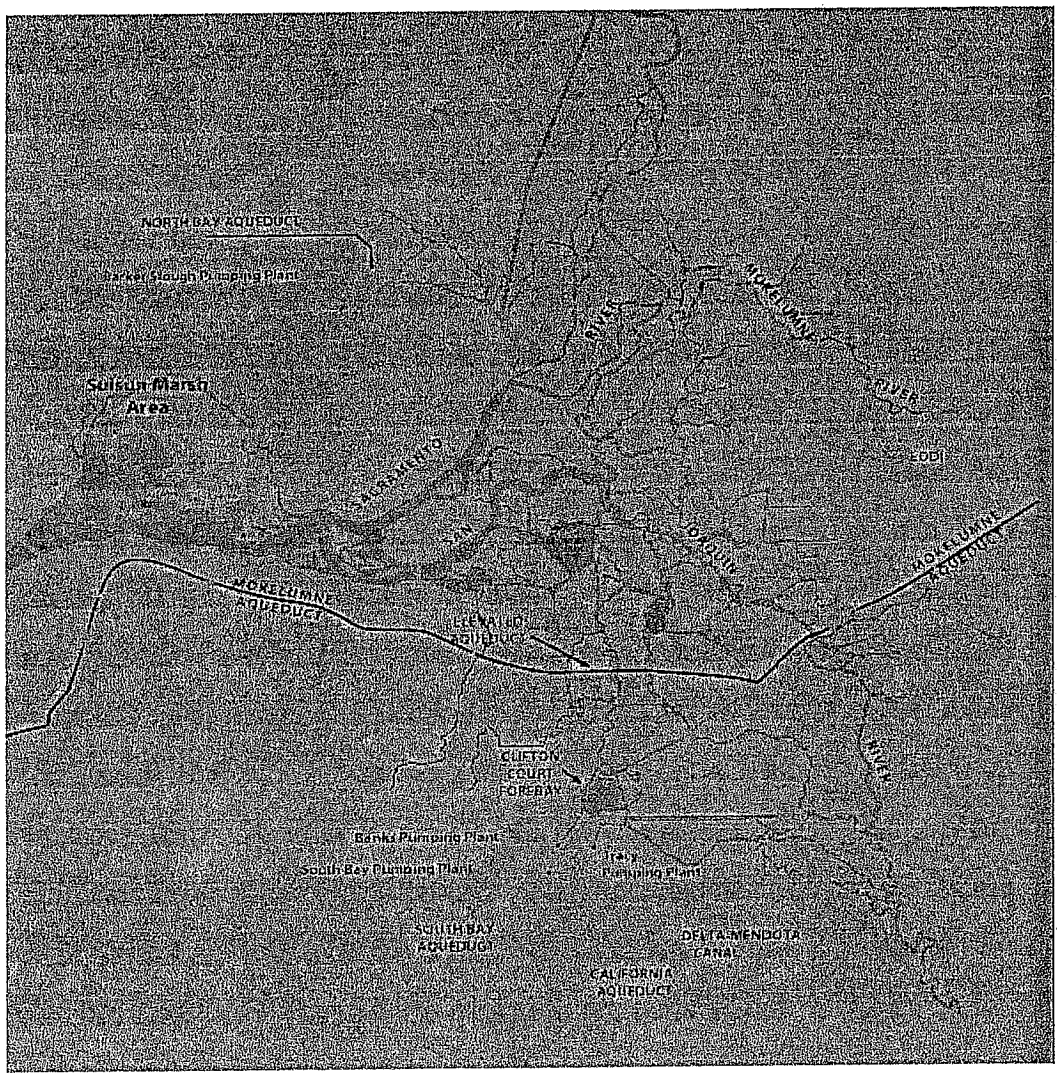
> *"A credible, certifiable EIR/EIS for the SDIP should include a detailed evaluation of the full range of water quality problems caused by the South Delta diversions and how they will be corrected as part of implementing the SDIP."*

Lee (2002) also stated,

> *"As discussed in these reports, the South Delta currently has significant water quality problems of low DO, currently-used pesticide caused aquatic life toxicity, legacy organochlorine pesticide excessive bioaccumulation in edible fish which are a threat to cause cancer in people who use the fish as food, excessive*

nutrients and elevated salts and TOC. Dr. Anne Jones-Lee and I have just completed a review for the Central Valley Regional Water Quality Control Board

Figure 1



on the organochlorine pesticide and PCB excessive bioaccumulation problems in Central Valley fish, which shows that Old River and Paradise Cut fish have excessive concentrations of legacy pesticides that are a threat to the health of those who use these fish as food."

There is no doubt that the existence and operation of the permanent operable barriers will have water quality impacts, many of which are not currently recognized.

A number of key factors will ultimately govern how the operable barriers are operated. Salinity is only one of those factors. Others include:

- potential impacts on the low-DO problems,
- excessive bioaccumulation of mercury, organochlorine "legacy" pesticides, and PCBs that accumulate in fish and other organism to threaten the health of those who eat those organisms,
- aquatic life toxicity, and
- other pollutants in several of the South Delta channels.

Lee and Jones-Lee (2004b) have provided a comprehensive review of Delta water quality issues that need attention as part of evaluating the potential impacts of the SDIP.

A review of the "Water Quality" section of the draft EIS/EIR shows that the draft EIS/EIR does not conform to CEQA requirements of providing full disclosure of potential environmental impacts of the proposed SDIP. Instead, consideration of water quality impacts has been essentially limited to potential impacts on salinity in South Delta Channels. The current modeling of salt, a conservative parameter, does not address the behavior and impacts of non-conservative pollutants such as pesticides that cause aquatic life toxicity. While there is mention of low-DO situations in some South Delta channels, the discussions are superficial and inadequate to inform the readers of the draft EIS/EIR about the potential impacts of the proposed increased export of water on the low-DO situation in South Delta channels.

The draft EIS/EIR also fails to address the large number of other water quality issues in the South Delta that have been impacted by the current water exports by the CVP and SWP and that will be exacerbated by the increased water exports that will occur if the proposed SDIP is approved. Further, there is no discussion of the impacts of the proposed operation of the operable barriers that are part of the proposed SDIP. As indicated above, the Lee and Jones-Lee (2004b) review of Delta water quality issues provides a discussion of the lack of understanding of impacts of the CVP and SWP on the large number of water quality issues that exist in the Delta overall and especially the South Delta. Many of the Delta channels have been listed as US EPA Clean Water Act (CWA) Section 303(d) impaired due to excessive concentrations of variety of pollutants compared to WQOs.

DWR and the USBR have not complied with SWRCB (2000) Water Rights D-1641 requirements to reliably delineate the potential impacts of exporting South Delta water on Delta water quality. Lee and Jones-Lee (2004b) observed that those agencies have

apparently convinced the IEP managers that the proposed exports will not cause any water quality impacts and that there is no need to conduct a comprehensive water quality monitoring/evaluation in the Delta to assess the impacts of the exports. The fallacy of that approach was clearly brought to light in the findings of an independent expert panel review of the current pelagic organism decline (POD) (POD Review, 2005). The POD has resulted in a crash program to attempt to quickly gather information to define and understand the potential combined impacts of CVP and SWP exports on POD. Lee and Jones-Lee (2005a) discussed the problems with that approach, which stem from the subtle nature of potential impacts of exports on water quality.

During the past six months we have been developing a San Joaquin River Water Quality Issues Report (Lee and Jones-Lee, 2006) as a follow-up to our Delta Water Quality Issues report (Lee and Jones-Lee, 2004a). Table 1, taken from Lee and Jones-Lee (2006), lists the current TMDLs for the SJR. The Lee and Jones-Lee (2002, 2006) SJR water quality issues reviews also list a number of potential water quality issues that could readily lead to CWA section 303(d) listings for the SJR that would require TMDLs to be developed to control the loads/conditions that are causing WQO violations.

WQO violations that occur in the SJR at Vernalis can also contribute to WQO violations in the South Delta as a result of the CVP and SWP export projects' drawing most of the SJR Vernalis water into the South Delta either through the Head of Old River or through Turner Cut. As discussed by Lee and Jones-Lee (2006), this results in the carrying of SJR water quality problems into the South Delta and to some extent into the Middle Delta. The proposed SDIP will amplify the water quality impacts of the SJR watershed as well as contribute locally derived pollutants. A credible EIS/EIR for the SDIP must include an evaluation of the potential impacts of the proposed increase in exports and an assessment of the impacts of the operation of the operable barriers on Delta water quality. This will require a large-scale, focused, comprehensive, multi-year monitoring and evaluation program, with particular attention to Delta aquatic life resources, to gather the background information needed to begin to reliably assess the potential impacts of the proposed SDIP on Delta water quality. The current POD studies are not focusing on many of the issues that will need to be addressed in order to develop a credible EIS/EIR for the SDIP.

Because of this major deficiency, the current draft EIS/EIR is inadequate and rejected as failing to comply with CEQA requirements. DWR and USBR should be required to fund a multi-year monitoring/evaluation program delineated by an independent panel of experts that would be responsible for organizing the studies, overseeing the implementation of the studies, reviewing results as they are developed, and reviewing the appropriateness of the draft reports and conclusions. This study program review should be conducted in a manner that provides the public with adequate opportunity to be informed of the progress and findings of the review and to provide and have considered comments on the approach and findings. It will take several years of study and assessment to obtain an adequate information base upon which to develop an EIR/EIR that could reliably assess the water quality impacts of the then proposed SDIP involving

increased CVP and SWP exports of South Delta water, and the potential consequences of various methods of operable barrier operation approaches.

Table 1. San Joaquin River Watershed TMDLs
Updated from Lee and Jones-Lee (2002)

Current (Active)
- Selenium
- Salinity at Vernalis, Total Dissolved Solids (TDS), Electrical Conductivity (EC)
- Boron
- Organophosphorus (OP) Pesticides (Diazinon, Chlorpyrifos)
- Oxygen-Demanding Substances (BOD/Algae, Ammonia, Organic N)

Pending (to be Developed)
- Organochlorine "Legacy" Pesticides (DDT, Chlordane, Dieldrin, Toxaphene, etc.)
- PCBs
- Dioxins/Furans
- Mercury
  - Sulfate (Bioaccumulation of Mercury)
- Pathogen-Indicator Organisms, *E. coli,* Fecal Coliforms
- Toxicity of Unknown Cause
- Salinity Upstream of Vernalis

Potential Future (to be Evaluated)
- Nutrients, Excessive Fertilization (Nitrogen and Phosphorus Compounds)
  - High pH, Low DO caused by Excessive Fertilization (Photosynthesis/Respiration)
- Alternative Pesticides to OP Pesticides including the Pyrethroid-Based Pesticides that are Causing Water Column and Sediment Toxicity
- PBDEs.
- Total Organic Carbon, and other chemicals such as Bromide that develop into Disinfection Byproducts (Trihalomethanes) in Treated Domestic Water Supplies
- Excessive Sediment, Erosion, Turbidity
- Herbicides (Toxicity to Algae)
- Aquatic Sediment Toxicity, (Pesticides, Nutrients/Algae/Sediment Ammonia, Heavy Metals, PAHs and other Chemicals)
- Unrecognized Pollutants
  - Pharmaceuticals and other Unregulated Chemicals Discharged by Confined Animal Facilities (dairies, feedlots, etc.) and domestic wastewaters

A key part of the monitoring/evaluation program should be an assessment of the mitigation that DWR/USBR would need to implement to eliminate, to the maximum extent practicable, the adverse water quality and aquatic life impacts of the current export of South Delta water for the projects.

One of the conditions that also need to be evaluated in this program is the beneficial impacts of reduced South Delta exports by CVP and SWP from the current conditions.

Incorporation of this approach is justified since the current water export rates were not based on a reliable assessment that they could be practiced without adverse impacts on Delta aquatic ecosystems.

The draft EIS/EIR Chapter 5 Section 3 presents DWR/USBR's assessment of SDIP impacts on "Water Quality". The introduction to that discussion states,

> *"5.3 Water Quality*
>
> *Introduction*
>
> *The maintenance of beneficial uses of Delta waters depends on several key water quality variables (e.g., salinity, water temperature, dissolved oxygen, and dissolved organic carbon) in Delta waters. This chapter describes these key water quality variables, the objectives associated with maintaining beneficial uses of Delta waters, existing Delta water quality conditions, and impacts of the SDIP project on selected water quality variables in Delta channels and exports."*

That chapter then reviews the perceived impacts of the SDIP increased exports and barrier operations on "Water Quality." It is stated in Chapter 5,

> *"Summary of Significant Impacts*
>
> *There are no significant impacts on water quality as a result of implementation of the project alternatives. Operation of the tidal gates provides substantial improvements in salinity in the south Delta channels. There are occasional slight increases in salinity occur in the CCWD intakes and at SWP Banks, but these are less than 5% of the baseline values. The water quality benefits are less under Alternative 4B, which includes constructing only the head of Old River gate."*

In the subsequent section it is stated,

> *"Affected Environment*
>
> *Delta waters serve several beneficial uses, each of which has water quality requirements and concerns associated with it. The Delta is a major habitat area for important species of fish and aquatic organisms, as well as a source of water for municipal, agricultural, recreational, and industrial uses. Dominant water quality variables that influence habitat and food-web relationships in the Delta are temperature, salinity, suspended sediments (SS) and associated light levels for photosynthesis, DO, pH, nutrients (nitrogen and phosphorus), DOC, and chlorophyll. Other key constituents that are monitored in water for municipal are bromide (Br–) concentrations (measured in raw water) and concentrations of THMs or other chemical by-products formed during the disinfection of water (measured in treated water).*

what about arsenic, selenium pesticides, mercury etc !!

That presentation of so-called water quality impacts illustrates one the fundamental flaws of DWR/USBR's approach to water quality evaluation. The focus of the DWR and

USBR discussion is on selected aspects of municipal and agriculture uses of Delta waters. Those who understand water quality know that water quality impacts of a proposed project must be evaluated from all perspectives, as they relate to the impairment of the beneficial uses of a waterbody. DWR/USBR considers water quality as being limited to the quality of the water that is exported. These agencies largely ignore the vast arena of conventional water quality issues associated with the impacts of pollutants on the beneficial uses of a waterbody.

Key

The federal congress defined water quality in the Clean Water Act in terms of all designated beneficial uses of a waterbody. By definition in the CWA, the exceedance of a water quality standard/objective is an impairment of beneficial uses of a waterbody that must be corrected. As discussed by Lee and Jones-Lee (2004b) there are highly significant water quality problems in the Delta that are caused by known chemicals that that occur at concentrations above the applicable WQO for the Delta channels. Most importantly with respect to Delta water quality, water manipulation/diversions/exports do impact how pollutants in the Delta impact aquatic life-related beneficial uses of Delta waters. Changing the flow of water in the Delta will impact the location and magnitude of pollutant impacts on aquatic life and other beneficial uses of Delta waters.

An example of this can be seen with the potential impacts in the SJR by sulfate that is brought into the South Delta by the CVP and SWP. The concentration of sulfate affects the methylation of mercury. The CVRWQCB (2005) has indicated that the manipulation of flows in the South Delta as part of DWR-proposed operation of the operable barriers could affect the distribution of sulfate in the South Delta channels which, in turn, could affect the bioaccumulation of mercury in edible fish. There is need to evaluate how the operation of the South Delta operable barriers that are scheduled to be installed and operational by 2009 could affect the bioaccumulation of mercury in South Delta fish.

we just wrote that!!! Yes!!!

In testimony before the SWRCB hearing on the DWR and USBR draft Cease and Desist Order to prevent violations of the South Delta Salinity standard established as part of D-1641, Lee (2005c) indicated that DWR, as part of developing the operation of the South Delta operable barriers, will need to expand its scope of evaluation of barrier operation to include not only EC but also the impact of sulfate on mercury bioaccumulation. In addition, that evaluation should include the impact of barrier operations on the impacts of the other pollutants on the CVRWQCB 303(d) list for South Delta channels and other constituents that, while not on the 303(d) list, are impacting South Delta water quality. Lee (2005c) also suggested that DWR needs to more reliably evaluate the potential benefits of installing low-head, reverse-flow pumping across the permanent operable barriers to bring more Sacramento River water into the South Delta. Adoption of this approach could be highly cost-effective in improving South Delta water quality as well as the quality of the CVP-exported water. It could also help solve the low-DO problem in the DWSC.

Overall, the draft EIS/EIR cannot be certified as a credible discussion of SDIP water quality impacts. It does not provide a reliable evaluation of how the increased exports

and operation of the barriers will impact the aquatic life related beneficial uses of the Delta.

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Background of Drs. G. Fred Lee and Anne Jones-Lee
Pertinent to Assessment of San Joaquin River and Delta Water Quality

Dr. G. Fred Lee is President of G. Fred Lee & Associates, a specialty environmental quality consulting firm located in El Macero, CA, near Sacramento. He and Dr. Anne Jones-Lee, the principals of the firm, work on issues, projects, and problems of water supply water quality, water and wastewater treatment, water pollution control in both fresh and marine surface waters, and solid and hazardous waste impact evaluation and management, with particular emphasis on groundwater quality protection. Their client base includes governmental agencies, industry, public interest groups, and individuals.

Dr. Lee earned a BA degree from San Jose State College in environmental health sciences in 1955, a Master of Science in Public Health degree focusing on water quality issues from the University of North Carolina in 1957, and a PhD degree in environmental engineering/environmental science from Harvard University in 1960. For a period of 30 years beginning in 1960, he held university graduate-level professorial teaching and research positions at several major US universities, including the University of Wisconsin, Madison, the University of Texas system, and Colorado State University. In the 1980's he was Distinguished Professor of Civil and Environmental Engineering at the New Jersey Institute of Technology and Director of the Site Assessment and Remediation division of a multi-university hazardous waste research center there; for a several-year period, he also served as Director of the Water Quality Program for the State of New Jersey Sea Grant Program. During his university teaching and research career he conducted in excess of five million dollars of research and published over 500 papers and reports on those efforts.

Dr. Anne Jones-Lee earned a BS degree in biology from Southern Methodist University and a PhD degree in Environmental Sciences in 1978 from the University of Texas at Dallas focusing on water quality evaluation and management. She held university professorial positions for 11 years in environmental engineering and environmental sciences. Most recently she held the position of Associate Professor of Civil and Environmental Engineering with tenure at the New Jersey Institute of Technology. She and Dr. Lee have worked together as a team since the mid-1970s.

In 1989, Dr. Lee retired from university teaching and research; with Dr. Jones-Lee he expanded his part-time consulting activities into a full-time activity, and moved their base of operation to the Central Valley of California. They have continued to be active in publishing the results of their studies; in the past 15 years they have developed another 600 papers and reports covering work they have done in their various areas of activity, one of which is San Joaquin River and Delta water quality.

Dr. Lee's areas of expertise include the fate, effects and impacts of chemical constituents and pathogens on various aspects of water quality/beneficial uses of waterbodies. He has frequently served as an adviser to local, state, national and international governmental agencies and other entities on a variety of aspects of water quality, including the development and implementation of water quality criteria and standards. He served as an

invited peer reviewer for the National Academies of Science and Engineering "Blue Book" of water quality criteria in 1972, a member of the American Fisheries Society Water Quality Committee that reviewed the US EPA's "Red Book" water quality criteria of 1976, and a US EPA invited peer reviewer in the early 1980s for the approach that the Agency then proposed, and ultimately adopted, for developing water quality criteria for protection of aquatic life. That criteria development approach is still in use today. Further, Dr Lee was involved as a US EPA invited peer reviewer for several criteria documents. His work on water quality issues is somewhat unusual, in that, in addition to having a strong background in the chemical and biological sciences pertinent to water quality evaluation, he has an engineering background that provides a foundation for developing and evaluating control programs for chemical constituents in point and nonpoint source discharges.

Dr. Lee's involvement in Delta water quality issues began in the late 1980's when, while still in New Jersey, he became involved in three different consulting projects in California; one was concerned with Delta water quality issues, another with Lake Tahoe water quality, and the third with groundwater quality protection in the San Gabriel Basin on behalf of the Metropolitan Water District of Southern California. As a consultant to Delta Wetlands on water quality issues associated with the development of in-Delta storage reservoirs he became familiar with Delta water quality issues. Since then, Dr. Lee's work on Delta water quality issues has included participating in various CALFED (now California Bay-Delta Authority – CBDA) committees, subcommittees, working groups, etc., concerned with water quality issues in the Delta and its tributaries.

Beginning in the mid-1990s Dr. Lee became involved in the details of water quality issues in both the Sacramento and San Joaquin River watersheds. One aspect of his involvement was as a volunteer technical advisor to the DeltaKeeper (William Jennings) to help the DeltaKeeper establish and maintain a technically sound grounding as it addresses issues pertinent to the protection and enhancement of water quality in the Delta and its tributaries. Dr. Lee's work with the DeltaKeeper has included such matters as managing aquatic life toxicity in the Central Valley and Delta caused by runoff/discharges of pesticides from agricultural and urban areas; reviewing and managing excessive bioaccumulation of organochlorine legacy pesticides and PCBs in Central Valley waterbodies and the Delta; reviewing potential environmental impacts of aquatic pesticides used for aquatic weed control in the Central Valley and Delta; assessing the impacts of flow management in and from the South Delta on water quality; and providing guidance on environmental aspects of dredging and dredged sediment management in the Delta.

Another key aspect of Dr. Lee's involvement continues to be the low-DO problem in the San Joaquin River Deep Water Ship Channel. In 1999, Dr. Lee began to work closely with the SJR DO TMDL Steering Committee, as well as the Central Valley Regional Water Quality Control Board (CVRWQCB) staff, in helping to improve the level and quality of science and engineering incorporated in the San Joaquin River low-DO TMDL program. Dr. Lee was awarded a contract with the CVRWQCB to develop an "Issues" report to identify and discuss the issues that need to be addressed as part of formulating a

TMDL to control the low-DO problem in the San Joaquin River DWSC (Lee and Jones-Lee, 2000).

Dr. Lee worked closely with the CVRWQCB lead staff (Dr. Chris Foe) in developing a coherent two-million-dollar proposal, which was funded by CALFED. Dr. Lee served as the coordinating PI for the 12 projects that were conducted under this proposal. From the work, Lee and Jones-Lee (2003) developed the "synthesis report" that presents a summary/synthesis of approximately four years and four million dollars of studies on the SJR DWSC low-DO problem. Since completion of that synthesis report in March 2003, Drs. Lee and Jones-Lee have continued to be active in Delta water quality issues and develop a supplement to synthesis report (Lee and Jones-Lee, 2004a). They have also developed a comprehensive report on Delta water quality issues (Lee and Jones-Lee, 2004b). Lee and Jones-Lee (2006) are developing a comprehensive report on San Joaquin River water quality issues. These and other reports on these issues are available from their website, www.gfredlee.com, in the San Joaquin River Watershed section at http://www.gfredlee.com/psjriv2.htm.

Further information on Drs. Lee and Jones-Lee's expertise and experience pertinent to assessment of Delta water quality issues is available on their website, www.gfredlee.com, or upon request.

References Cited in Qualifications

Lee, G. F. and Jones-Lee, A., "Issues in Developing the San Joaquin River Deep Water Ship Channel DO TMDL," Report to Central Valley Regional Water Quality Board, Sacramento, CA, Report of G. Fred Lee & Associates, El Macero, CA, August (2000). http://www.gfredlee.com/sjrpt081600.pdf

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re: SDIP

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Southwest Region
501 West Ocean Boulevard, Suite 4200
Long Beach, California 90802-4213

January 11, 2007

In response refer to:
2006/03464

attachment #2

Alan R. Candlish
Regional Planning Officer
Bureau of Reclamation
Mid-Pacific Regional Office
2800 Cottage Way
Sacramento, California 95825-1898

Dear Mr. Candlish:

NOAA's National Marine Fisheries Service's (NMFS) intends to suspend formal consultation for the South Delta Improvements Program (SDIP). During the course of the project effects analysis, several areas of significant concern arose. These concerns were:

1. The interrelated aspects of the SDIP barrier construction actions with the long term operations of the Central Valley Project (CVP) and State Water Project (SWP) under the operations and criteria plan (OCAP). Analysis of the SDIP as a separate project without consideration of how it will be used under OCAP would be seen as piecemealing under the Endangered Species Act. The stated objectives and purposes of the SDIP confirm the interdependence and interrelatedness of the two projects.

   - Increase water supply to the SWP and the CVP water contractors south of the Delta by increasing diversions at the existing Clifton Court Forebay radial gates and maximizing the frequency of 8,500 cubic feet per second (cfs) pumping at the Harvey O. Banks Pumping Plant (Banks).

   - Ensure water of adequate quantity and quality for agricultural diverters within the south Delta.

   - Reduce entrainment of Central Valley fall/late fall-run Chinook salmon (*Oncorhynchus tshawytscha*) from the San Joaquin River.

2. The CalSim-II (SWP and CVP Operating Model) modeling analysis done for the SDIP is no longer in harmony with the current modeling being done for the reinitiated OCAP consultation. NMFS staff is aware of the changes being considered for the baseline programming assumptions in the reinitiated OCAP consultation, and has previously indicated that both SDIP and OCAP computer

simulations must be based on the same common modeling assumptions to be valid and comparable.

3. The modeling conducted for the SDIP actions neglected to assess the use of the permanent barriers with the current level of water diversion (6,680 cfs). This modeling run is important to know since the future increase in the SWP diversion rate to 8,500 cfs is not a guaranteed action. The "baseline" modeling done with the permanent barriers under the 2004 OCAP modeling runs assumed that the diversion rate was 8,500 cfs. The "interim" period of barrier operations between completion of construction and the increase to water diversions of 8,500 cfs has not been presented to NMFS staff in the Action Specific Implementation Plan.

4. The true baseline conditions in the South Delta occur during the period between November 30 and April 7 of each year when the barriers are absent from the channels of the South Delta. The alterations in hydrology of the barrier installations from the true baseline have not been presented in a coherent fashion within the modeling run outputs.

NMFS recommends that the SDIP Stage 1 (and stage 2) actions be incorporated into the overarching OCAP action. This will avoid inconsistencies with the modeling assumptions between the two actions. In addition, by combining the two actions into one, all of the interacting effects of the two proposed actions are addressed at the same time in one consultation rather than breaking the effects into two consultations. This avoids the appearance of piecemealing the projects. Although other activities linked to OCAP have been proposed (*e.g.*, Yuba Accord water transfers, Red Bluff Diversion Dam Fish Passage Improvement Program, *etc.*), their potential effects to water operations are less clear. These activities will be evaluated for inclusion in the OCAP consultation on a case-by-case basis.

Please contact Mr. Jeffrey Stuart at 916-930-3607, or via e-mail at J.Stuart@noaa.gov if you have any questions concerning this response or require any additional information.

Sincerely,

for Rodney R. McInnis
Regional Administrator

cc: Copy to file – ARN 151422SWA1999SA5950
NMFS-PRD, Long Beach, CA
Katherine F. Kelly, Chief, Bay-Delta Office, California Department of Water Resources, 1416 9th Street, Sacramento, CA 95814

attachment #3

Natural Resources Defense Council
Environmental Defense
The Bay Institute
Planning and Conservation League
California Sportfishing Protection Alliance

April 26, 2007

Ryan Broddrick, Director
Department of Fish and Game
1416 Ninth Street, 12th Floor
Sacramento, CA 95814

Re: Department of Water Resources' Request for a CESA Consistency Determination

Dear Director Broddrick:

We are writing on behalf of numerous environmental and fishing organizations representing hundreds of thousands of Californians to urge you to deny the Department of Water Resources' ("DWRs'") pending request for a consistency determination under the California Endangered Species Act ("CESA") for its continuing, status quo operation of the State Water Project ("SWP"). DWR asks you to determine that listed salmonids and imperiled delta smelt will be adequately protected under the federal biological opinions for the joint operations of the Central Valley Project ("CVP") and SWP (the "Operating Criteria and Plan" or "OCAP"). However, those biological opinions – one of which addresses impacts to delta smelt (the "smelt BO") and one of which addresses impacts to listed salmon and steelhead (the "salmon BO") – have been explicitly disavowed by the agencies party to those biological opinions, including DWR, as well as numerous independent scientific reviewers. Further, DWR asks you to allow it to continue operating under those biological opinions, even though the biological opinions have failed to stem the tide of crashing Delta fisheries over the last several years that they have been in effect. Finally, DWR asks you to allow it to continue operating under those biological opinions, even though more recent scientific evidence and the requirements of CESA militate against it.

Instead of adopting DWR's unlawful and ineffective approach to addressing its ongoing CESA violations, we urge you to require DWR to take steps to protect listed species and to mitigate the adverse effects of the SWP, as required by CESA. At the bare minimum, such steps include fully implementing all of the actions that DWR and the Department of Fish and Game ("DFG") have already acknowledged are necessary to "address the pelagic organism decline (POD) and stabilize the ecosystem in the Sacramento-San

Joaquin Delta." Resources Agency, Pelagic Fish Action Plan (March 2007) at 4 ("Action Plan"). If DFG cannot require those minimal actions through a consistency determination, DFG should immediately request DWR to submit an application for an incidental take permit. As the Action Plan recognizes, the existing federal biological opinions on which DWR seeks to rely are undergoing re-consultation which "will help formulate a more accurate and comprehensive approach to improving Delta ecosystem health for pelagic fish." *Id.* Until that re-consultation is complete and the new biological opinions are shown to be consistent with CESA, DFG should require DWR, at a minimum, to fully implement and fully fund all of the actions in the Action Plan.

Among other things, the Action Plan indicates that DFG seeks to secure a specific commitment of water from DWR. Action Plan, p. 37. Unfortunately, DWR has not, to date, committed sufficient amounts of water necessary to protect delta smelt and salmon. DFG's authority under CESA provides the mechanism by which DFG must require the necessary commitments of water and specific operational changes from DWR. As indicated below, we believe that additional actions are required; however, anything less than the Action Plan clearly fails to comply with CESA.

I. THE FEDERAL BIOLOGICAL OPINIONS FAIL TO MEET THE REQUIREMENTS OF CESA

Section 2080.1 of the Fish and Game Code identifies the limited circumstances under which DFG may issue a consistency determination. It may do so only if the federal "incidental take statement or incidental take permit is consistent with this chapter", which includes all the requirements of CESA. Fish and Game Code § 2080.1(c). CESA includes two requirements that are of particular relevance here. First, DFG may only authorize take of endangered, threatened and candidate species if *all* of the following conditions are met: (1) the impacts of the authorized take "shall be minimized and fully mitigated" to an extent "roughly proportional" to the impact of the authorized taking on the species; (2) the proposed mitigation measures "shall be capable of successful implementation"; and (3) the applicant "shall ensure adequate funding to implement" the mitigation measures "and for monitoring compliance with, and effectiveness of, those measures." *Id.*, § 2081(b). Second, no permit may be issued if issuance of the permit would jeopardize the continued existence of the species "based on the best scientific and other information that is reasonably available" and considering any adverse impacts of the taking in light of "known population trends, known threats to the species, and reasonably foreseeable impacts on the species from other related projects and activities." *Id.*, § 2081(c). DWR has not and cannot demonstrate that its continued operation under the federal OCAP biological opinions would meet these requirements here.

A. The Federal BOs Do Not Satisfy CESA's Mitigation Requirements

The federal Endangered Species Act does not require, as CESA does, that the impacts of taking a covered species be "minimized or fully mitigated" to an extent "roughly proportional" to the impact of the authorized activity. Thus, the federal BOs on which DWR seeks to rely do not require "minimization" or "full mitigation" of the take authorized therein. For this reason alone, the federal BOs do not suffice to meet all the requirements of CESA.

In addition, to the extent that the federal BOs rely on purported mitigation measures to conclude that the OCAP will not cause jeopardy to listed species or adverse modification of critical habitat, those measures are uncertain and unproven, and do not meet CESA's requirements of being "capable of successful implementation," of being "adequately funded," or of being adequately monitored. *See* Fish and Game Code, § 2081(b). For example, as explained in the attached briefs filed in the pending action challenging the adequacy of the smelt BO, the lynchpin of the smelt BO is a fluid and unenforceable "adaptive management" scheme using the Delta Smelt Risk Assessment Matrix ("DSRAM"). *See, e.g., NRDC v. Norton,* Plaintiffs' Memorandum of Points and Authorities in Support of Motion for Summary Judgment (June 9, 2006) at 9-16 (appended as Exhibit 1). However, the DSRAM as described in the BO requires nothing more than discretionary meetings and paperwork, and explicitly does not require implementation of *any* decision, even if unanimously recommended by every expert fisheries biologist from the numerous agencies represented on the Delta Smelt Working Group ("DSWG"). Instead, the smelt BO gives DWR and the U.S. Bureau of Reclamation, via the "Water Operations Management Team," an explicit veto over any mitigation measure or action recommended by the DSWG. *Id.*; *see also NRDC v. Norton,* Plaintiffs' Reply in Support of Motion for Summary Judgment (Jan. 22, 2007) at 14-19 (appended as Exhibit 2). In short, there is absolutely no assurance that any mitigation measure can or would be successfully implemented under the DSRAM process which lies at the heart of the federal smelt BO.

The smelt BO further relies on several mitigation measures that are most certainly not "adequately funded" or being implemented as anticipated in the document. These include the Environmental Water Account, CVPIA b(2), and the Vernalis Adaptive Management Plan ("VAMP"), none of which are supplying sufficient amounts of "environmental water" to cover necessary mitigation actions or to protect listed fish in the Delta or fish habitat. FWS recognized the uncertainty of these measures in the smelt BO itself, stating that "[a]lthough VAMP and the Environmental Water Account have helped to ameliorate [threats resulting from operation of the State and Federal water projects], it is unclear how effective these will continue to be over time based on available funding and future demands for water." *NRDC v. Norton,* Pls.' Mem. of P&A, at 14.

Since the smelt BO was finalized, it has become quite clear that these measures are not providing the amount of water necessary to support essential protective actions. For example, over the last several months, the DSWG has evaluated a range of protective actions that could be taken to lessen the impacts of water project operations. One action that was evaluated was to address fall (September-December) Delta salinity levels by making releases from upstream reservoirs to increase Delta outflows. The discussions and analyses of this proposed action are reported in DSWG notes for July 10 (with an appendix with the analyses dated June 17), August 21, August 30, and Sept 26 (appended hereto as Exhibits 3 - 6). The DSWG determined that the fall action had a high likelihood of being successfully implemented and that the scientific basis for the action was supported by statistically significant correlations.

Unfortunately, the fall action was not taken because it was determined that "the amounts of water needed to demonstrably improve fall habitat quantity/quality [were] unavailable". Based on analyses provided by DWR, the amount of water necessary for maintaining net Delta outflows at 7000 cfs for the September-December period would range from only 170-433 TAF. Delta Smelt Working Group notes (Aug. 21, 2006). As a result of not taking this action, Delta outflows steadily declined, falling below 6000 cfs in October, and salinity levels shifted upstream of 80 km, the critical threshold identified by the DSWG for delta smelt habitat quality and subsequent abundance. It is too soon to know the actual quantitative impact this has had on populations, but it is safe to assert that higher salinity levels did not improve conditions for smelt.[1]

Perceived unavailability of water assets was also the reason behind the DSWG rejecting a protective action this winter intended to set net flows in Old and Middle Rivers to zero cfs to better protect pre-spawning adults. Low San Joaquin River inflows and negative flows on Old and Middle Rivers, concurrent with high export rates, are likely creating hydrodynamic conditions that draw greater numbers of fish to the pumps and correspond to significantly higher salvage rates. Protection of these biologically valuable spawning adult fish is essential for recovery and sustainability of this at-risk species. Despite the expected benefit of taking this action, it was rejected because "DWR staff have derived estimates of the water costs of the potential actions in the Resources Agency POD Action Matrix and found that the proposed winter action could consume all available

[1] While the specific impact of the failure to take this fall action may still be unclear, there is no doubt that the delta smelt continues to face perilous conditions following implementation of the smelt BO. At the April 12, 2007 Fish and Game Commission hearing, DFG acknowledged that the delta smelt currently faces imminent risk of extinction and merits endangered status. Given that this decline in the smelt's condition occurred and has continued under the current smelt BO, its measures are clearly insufficient to protect and recover this species. *See* The Bay Institute *et al.*, Petition to the State of California Fish and Game Commission and supporting information for listing the Delta Smelt (Hypomesus transpacificus) as an endangered species under the California Endangered Species Act (Feb. 7, 2007) (appended as Exhibit 15).

environmental water, leaving no assets for spring actions for larvae or juveniles." Delta Smelt Working Group notes (Dec. 11, 2006) (appended as Exhibit 7).

There is no doubt that in past years the water promised through the CALFED ROD through both the Environmental Water Account and the CVPIA (b)(2) account has been significantly less than what was promised in the CALFED ROD, and assumed in the federal BOs. *Finding the Water: New Water Supply Opportunities to Revive the San Francisco Bay-Delta*, Environmental Defense, 2005 (appended as Exhibit 8). This shortfall has been as much as 500,000 acre-feet per year. Nevertheless, the federal BOs do not provide adequate mechanisms "for monitoring compliance with, and effectiveness of" these and other mitigation measures. Fish and Game Code § 2081(b). For example, the BOs do not require the agencies to ensure that the assumed levels of "environmental water" will be provided, nor do those BOs impose any contingency measures in the event that sufficient "environmental water" is not provided. Such mechanisms must be part of any adequate CESA compliance.

The salmon BO suffers many of the same problems as the smelt BO, relying on uncertain mitigation measures that are not adequately funded nor effectively monitored. *See, e.g., PCFFA v. Gutierrez*, First Amended Complaint w/Attachments (Sept. 11, 2006) (appended as Exhibit 9). The salmon BO provides for an "adaptive management" process under which the Bureau, NMFS and the FWS would discuss potential changes in water storage and release to benefit the five listed salmonids, but does not provide any assurance of any particular level of protection for the listed species as a result of this promise of future "adaptive management," nor does it identify reasonably certain, enforceable measures that would be implemented if changes in operations were necessary to protect the species.

The salmon BO also permits substantial backsliding from protections that previously existed for listed salmonids. For example, the salmon BO moves the temperature compliance point upstream from Bend Bridge to Ball's Ferry, and eliminates the Shasta carryover requirement necessary to maintain adequate cold water reserves for salmonids. DFG biologists have previously expressed their concern about this backsliding, stating that "DFG salmon biologist[s] do not support the proposal to move the temperature compliance point up-stream. It has been calculated that up to sixty river miles of habitat will be impacted by this proposed change in the temperature compliance point." Email from James Starr, DFG (April 23, 2004) (attached as Exhibit 10). Before abruptly changing their minds in the final salmon BO, biologists at NMFS concurred, stating that: "NOAA Fisheries is concerned that shifting the temperature compliance point upstream could result in a large loss of winter-run Chinook spawning habitat. Winter-run Chinook spawning habitat in the Sacramento River is currently restricted to a short distance of mainstem habitat below Shasta Dam. Moving the temperature compliance point further upstream would seriously reduce the already restricted spawning area afforded to winter-run Chinook salmon in the Sacramento River." Letter from Rodney McInnis, Regional

Administrator, NMFS, to Mr. Thomas Stokely, Trinity County (Jul. 23, 2004) at 2 (attached as Exhibit 11). DWR, DFG and the State Water Resources Control Board have similarly acknowledged that the salmon BO will have greater, unmitigated impacts on listed salmonids than the biological opinions it replaces, stating in a May 17, 2005 letter to Senator Machado that "the State anticipates increased impacts to winter-run and spring-run Chinook will occur as a result of the changes in water project operation and less stringent temperature compliance requirements." *PCFFA v. Gutierrez*, First Amended Complaint at 27.

In addition, the salmon BO allows for a known salmon migration obstacle – the Red Bluff Diversion Dam – to continue operating in the "gates-in" position for four months out of the year.[2] The agencies have recognized for years now that this operation of Red Bluff Diversion Dam is deadly to a large percentage of listed salmonids, stating in a 2002 Draft Environmental Impact Statement/Environmental Impact Report that 72 percent of adult spring-run Chinook salmon and over 35 percent of juvenile winter-run Chinook and steelhead are adversely affected by the operation of the Dam. Red Bluff Diversion Dam DEIS/EIR (Sept. 5, 2002) at ix (available at http://www.usbr.gov/mp/nepa/nepa_projdetails.cfm?Project_ID=237). Gates-in operation also "results in complete blockage of migrating adult green sturgeon" and adversely affects "approximately 99 percent of annual juvenile green sturgeon passing RBDD." Red Bluff Diversion Dam DEIS/EIR, p. B-15. DFG, along with the U.S. Fish and Wildlife Service, the National Marine Fisheries Service, and the California Advisory Committee on Salmon and Steelhead Trout, have all previously endorsed year-round gates-out operation of Red Bluff Diversion Dam as the only alternative acceptable for protecting listed salmonids. *See, e.g.*, Red Bluff Diversion Dam DEIS/EIR, pp. 1-13 to 1-14, Appendix G, Appendix I. DFG has further explained that "The RBDD fish passage problem is considered one of the highest priority projects to attain the objectives for salmon and steelhead restoration." *Id.*, App. I. Moreover, several agencies note that a large amount of taxpayer funds has been expended for habitat restoration *upstream* of the Dam, but a large percentage of listed fish cannot reach that restored habitat due to the current operations of RBDD. *Id.*, App. I, Draft Report, p. 16.

In sum, neither the smelt BO nor the salmon BO was designed nor functions to meet the requirements of CESA.

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[2] On April 24, 2007, the Bureau of Reclamation announced that it would close Red Bluff Diversion Dam for *more* than four months this year to meet "earlier-than-usual agricultural water demands resulting from a dry, warm spring." USBR, press release, "Closure of Red Bluff Diversion Dam Gates Scheduled Early to Meet Water Demands", April 24, 2007 (available at http://www.usbr.gov/newsroom/newsrelease/detail.cfm?RecordID=16641).

B. The "No Jeopardy" Conclusions of the Federal BOs Are Not Based on the Best Scientific Information, as CESA Requires

As explained above, CESA prohibits DFG from issuing a consistency determination if the permit would jeopardize the continued existence of the species "based on the best scientific and other information that is reasonably available" and considering any adverse impacts of the taking in light of "known population trends, known threats to the species, and reasonably foreseeable impacts on the species from other related projects and activities." Fish and Game Code § 2081(c). The federal agencies party to the federal BOs and several independent scientific panels have already explained that the federal BOs are *not* based on the best scientific information available, nor do they adequately consider impacts of the taking in light of known population trends, known threats to the species, or reasonably foreseeable impacts from other related projects and activities. Thus, DWR's requested consistency determination also fails to satisfy this requirement of CESA.

1. Several Federal Agencies And DWR Have Acknowledged the Smelt BO is Woefully Out-of-Date

The U.S. Fish and Wildlife Service and Bureau of Reclamation explain in the attached brief that it is precisely the failure of the smelt BO to reflect recent scientific information and known threats that prompted the agencies to reinitiate ESA section 7 consultation. *See NRDC v. Kempthorne*, Federal Defendants' Response to Plaintiffs' Motion for Summary Judgment and Cross-Motion to Dismiss, or in the Alternative, Motion for Voluntary Remand (July 14, 2006) (appended as Exhibit 12). DWR has explicitly joined in their findings, thereby acknowledging that the smelt BO fails to meet the requirements of CESA. *NRDC v. Kempthorne*, California Department of Water Resources' Joinder in the Federal Defendants' Motion to Dismiss or, In the Alternative, Motion for Voluntary Remand and Joinder in Federal Defendants' Supplemental Motion for Stay (Nov. 1, 2006) at 2 (appended as Exhibit 13.)

Among other things, these agencies recognize that the smelt BO is not based on "known population trends" or consideration of the substantial population declines experienced by the smelt in recent years. *NRDC v. Kempthorne*, Federal Defendants' Response to Plaintiffs' Motion for Summary Judgment and Cross-Motion to Dismiss, or in the Alternative, Motion for Voluntary Remand, at 4. They also recognize that the smelt BO is not based on the best scientific information or the known threats to the species revealed in the 2005 IEP POD synthesis and more recent POD studies. *Id.* at 4-5. Nor does the smelt BO include consideration of the impacts of climate change on the Delta and its ecosystem, including DWR's own July, 2006 climate change report that, according to the federal agencies, "requires further consideration." *Id.* at 6. Even the project description of the smelt BO is admittedly out-of-date, failing to reflect current information on American River Flow Standards, Water Transfers, the Delta Mendota-California

Aqueduct Intertie, Sac River Reliability Study, M & I Shortages, Article 21, EWA as modeled, and more. *Id.* at 5-6.

Collectively, these shortcomings in the smelt BO have led the agencies, including DWR, to conclude that the 2005 smelt BO will likely be affected in "at least three ways" in the current re-consultation:

> First, the environmental baseline and jeopardy analysis will be revisited, because whether or not the OCAP implementation will appreciably reduce the likelihood of survival and recovery of the delta smelt must be evaluated against what may likely be a new baseline, potentially with a lower species population than was previously understood to exist. Second, the critical habitat analysis will be revisited, because data on salinity concentrations, declining population recruitment activity from downstream areas, and invasion of the exotic clam species, *potamocorbula amurensis*, require further analysis of whether the implementation of the OCAP adversely modifies critical habitat, in terms of both survival and recovery of the species. Third, and finally, the existing incidental take statement may need to be revised to take into account recent delta smelt population changes.

Id. at 6. In other words, the smelt BO will likely undergo significant changes once it does incorporate the best and most recent available science, rendering DFG's and DWR's reliance on the document for CESA compliance at this time both unwise and unlawful.

2. Several Independent Studies Have Thoroughly Discredited the Salmon BO

On October 22, 2004, NMFS released its biological opinion on the impacts of the 2004 OCAP on federally listed salmon and steelhead. The salmon BO documents the severe decline of these species due to the joint operations of the CVP and SWP, and the substantial adverse impacts that the 2004 OCAP would have on those species. Nevertheless, the final BO, in contrast to the "jeopardy" conclusion of at least one draft BO, found that the 2004 OCAP would not jeopardize the continued existence of any listed salmonid or adversely modify critical habitat. In April and May, 2006, the Bureau of Reclamation requested reinitiation of consultation on the OCAP, recognizing that "new information has been developed since issuance of the 2004 OCAP Biological Opinion in October, 2004, and that this information will be considered in the consultation." Letter from Ronald Milligan, USBR, to Rodney McInnis, NMFS (May 19, 2006). Thus, like the smelt BO, the federal agencies have acknowledged that the salmon BO does not reflect the best scientific information currently available, as required by CESA.

Moreover, the salmon BO has undergone several independent reviews, all of which have

echoed this finding. Because of the abrupt and apparently unjustified alteration of the finding of the final salmon BO to "no jeopardy" and "no adverse modification" from the contrary conclusions in the draft BO, U.S. Senator Barbara Boxer (D-CA) called for an investigation to determine whether improper political pressure had been placed upon NMFS to change the draft Biological Opinion's jeopardy conclusions. U.S. Rep. George Miller (D-Martinez) and 18 other members of Congress also asked the Inspectors General of the Interior and Commerce departments to investigate whether federal political appointees played a role in encouraging NMFS to ignore the scientific basis for the initial jeopardy conclusions and to override those conclusions.[3] State Senator Michael Machado, chair of the Natural Resources and Water Subcommittee on Delta Resources, made a similar request.

In response to these Congressional concerns, on July 8, 2005, the Department of Commerce's Inspector General issued a report on the NMFS consultation on the 2004 OCAP ("IG Report"). Appended as Attachment 1 to Exhibit 9. The IG Report criticized NMFS for "bypass[ing] key internal controls over the integrity of the biological opinion," and stated that the flawed process leading up to the issuance of the salmon BO "raises questions about the integrity of that OCAP opinion." *Id.* at 16. The IG Report noted that neither NMFS's regional ESA Section 7 coordinator nor its Office of Regional Counsel reviewed the salmon BO, contrary to NMFS's own internal procedures. *Id.* at 10-13. The IG Report stated that, in any case, the regional ESA Section 7 Coordinator "would not have signed off on the opinion because of her belief that there is a basic disconnect between the scientific analysis and the [no jeopardy] conclusion." *Id.* at 11.

Following one of the recommendations in the IG Report, NMFS asked a panel of independent fisheries biologists from the California Bay-Delta Authority ("CALFED") Science Program to review the salmon BO and determine whether NMFS had used the best available science in developing it. On January 3, 2006, the CALFED panel issued a report unanimously concluding that NMFS had *not* used the best available science. Appended as Attachment 2 to Exhibit 9. The CALFED report identified no fewer than fifteen technical deficiencies in the salmon BO, including "[l]ack of a comprehensive population approach to jeopardy assessment," "[t]oo little attention devoted to the effects of future global climate change," and "[u]nclear connection between the analyses and the findings in the [Biological Opinion]."

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[3] A recently released Inspector General report on the improper interference of Deputy Assistant for Fish and Wildlife and Parks, Julie MacDonald, with the scientific findings of Fish and Wildlife staff confirms that this type of political interference occurred on numerous occasions in the Bush Administration. *See*, U.S. Dept. of Interior, Office of Inspector General, Report of Investigation, Julie MacDonald (Mar. 23, 2007) (appended as Exhibit 14). The report confirms "that MacDonald has been heavily involved with editing, commenting on, and reshaping the Endangered Species Program's scientific reports from the field [despite the fact that] she has no formal educational background in natural sciences, such as biology." *Id.* at 2.

NMFS also requested that scientists from the Center for Independent Experts ("CIE") in Miami, Florida review the salmon BO to determine whether NMFS had used the best available science. On January 12, 2006, one of the two CIE reviewers concluded that the salmon BO was *not* based on the best available science. Appended as Attachment 3 to Exhibit 9. That reviewer criticized numerous elements of the biological opinion, including its failure to examine the relative significance of various threats to salmon species, its failure to take into account substantial uncertainty brought about by less than optimal modeling and data, and its failure to support statements in the salmon BO with actual data. The reviewer also noted that "one of the main assumptions [in the Biological Opinion], that past weather observations are indicative of the future, is neither clearly stated nor reasonable." *Id.* at 2. The second CIE reviewer, while characterizing the salmon BO as "a good faith effort," also pointed out numerous shortcomings in NMFS's analysis. Appended as Attachment 4 to Exhibit 9.

On March 29, 2006, the Department of Commerce Inspector General issued a memorandum demanding that NMFS's parent agency, the National Oceanic and Atmospheric Administration ("NOAA"), submit "a written response regarding NOAA's plan to address the deficiencies and related recommendations made in the scientific reviews," and stating that "it is clear that additional steps should be taken in light of the results of these independent analyses that the scientific integrity of the biological opinion was impaired." Appended as Attachment 5 to Exhibit 9.

In light of these findings, neither DWR nor DFG has any grounds to assert that the salmon BO is based on the best scientific information, as required by CESA.

II. THE PELAGIC FISH ACTION PLAN DEFINES THE MINIMUM STEPS THAT DFG SHOULD REQUIRE OF DWR

In response to a directive from the legislature in June 2006, the Resources Agency embarked on developing a plan to address the dramatic decline in pelagic organisms and the need to stabilize the ecosystem in the Sacramento-San Joaquin Delta. Based on significant scientific study and analysis conducted on behalf of the Interagency Ecological Program as well as numerous independent experts, the Pelagic Fish Action Plan was released in March of 2007 to provide recommended actions for improving conditions for pelagic fish species and for helping to stabilize the Delta ecosystem.

The Action Plan outlines three recommendations to modify water project operations to benefit pelagic species. These actions focus on reducing adult delta smelt and larvae entrainment at the SWP and CVP intakes, providing better spawning distribution, and increasing the availability of delta smelt habitat. While these are all key actions for protecting critical life stages of the smelt and for possibly minimizing harm to species, the actions may be insufficient to reverse the decline of the species.

Improved scientific understanding of delta smelt has indicated that increasing the magnitude (i.e., duration of action, greater reduction in exports, etc.) of the actions in the Action Plan would better recreate the spawning and rearing environment to the one in which the delta smelt evolved and would further reduce entrainment of adults and larvae at the pumps.[4] Of particular concern is the emerging science indicating that the current management of the pumps is taking a significant number of larval and juvenile smelt hatched before the Vernalis Adaptive Management Program (VAMP) period. Herbold, B. C. S. Armor, R. Baxter, M. W. Chotkowski, M. Gringas, A. B. Mueller-Solger, M. L. Nobriga, and T. R. Sommer. 2006. POD conceptual synthesis. CALFED Science Conference, October 23-25, 2006, Sacramento, CA. (Abstract available at: http://sciconf.abag.ca.gov/conferences/abstract_view_01a.php). It is therefore recommended that the VAMP export curtailment be extended beyond the required 31-day period until monitoring and salvage indicate that the majority of the delta smelt population is located downstream of the confluence of the Sacramento and San Joaquin Rivers.

At an absolute *minimum* there must be a commitment that all of the operational actions outlined in the Action Plan will be *fully* implemented to prevent further harm to pelagic species. In order to fully implement the Action Plan, it is critical that a firm commitment be made from DWR to dedicate a significant amount water on an annual basis that well exceed the currently undersized and unreliable EWA.[5] Anything less will result in the fisheries agencies being constrained to take actions based on what water is made available to them, which in the past has been led to an inability to fully protect the species.[6] The Action Plan itself refers to the limited ability of the EWA to adequately allow proposed actions to be taken and that if jeopardy is to be avoided additional water need to be provided by the SWP and/or CVP.[7] Only 210-250 TAF is available in Tier 2 of the EWA for WY 2007, which clearly will not be sufficient to allow full implementation of the Action Plan.

Given that the population of the Delta smelt is so low, it is also imperative that in addition to the current monitoring underway, new real-time monitoring be in place to detect presence of larval and small juvenile Delta smelt at and near the pumping facilities. Emerging science is now indicating that this segment of the population is heavily impacted by entrainment at the pumps, but the exact impact is not yet known.

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[4] Letter from Peter Moyle, Ph.D. and Christina Swanson, Ph.D. to USFWS, DFG, NMFS, USBR, and DWR regarding Recommendations for Actions to Protect Delta Smelt, March 13, 2007.

[5] As outlined in the Action Plan, in some years it may require up to 1-1.5 million acre-feet to fully implement the operational actions specified in the plan. The EWA is currently sized at 210-250 TAF/yr.

[6] Finding the Water: New Water Supply Opportunities to Revive the San Francisco Bay-Delta, Environmental Defense, 2005.

[7] Action Plan, page 37.

Since many of the actions in the Action Plan are triggered by presence of smelt, there is a need for the more comprehensive monitoring data to be used to make this assessment.

DFG should require DWR to implement the actions set forth in the Action Plan, plus any necessary additional actions, through the issuance of an incidental take permit ("ITP"), rather than the questionable route of a consistency determination for the existing federal biological opinions. Some existing environmental documents may assist DFG in securing necessary and timely compliance with CEQA. The Action Plan itself indicates that all three of the actions affecting the SWP pumps can be implemented immediately and without further environmental review. *See* Action Plan, pp. 43, 45, 47, 48. An immediate ITP could serve as a bridge to a new or reissued ITP at the end of 2007.

III. PHYSICAL HABITAT RESTORATION MEASURES ARE ALSO REQUIRED BY CESA

The stated intent of the OCAP BOs is to provide ESA compliance for the vast majority of the operations of the CVP and SWP under the ESA. The operations of the Delta pumps, as discussed above, are among the most significant aspects of the CVP and SWP, from the perspective of endangered species protection. However, CESA requires the consideration of additional actions, particularly physical habitat restoration measures designed to fulfill the CESA requirement for full mitigation.

A. The Operation of Red Bluff Diversion Dam has Significant Impacts on State-Listed Species

As explained above, the current four-month gates-in operation of Red Bluff Diversion Dam has significant, unmitigated adverse impacts on listed salmonids. Not only does Dam operation impede salmonid migration and spawning success, it creates enormous predation problems and blocks passage to spawning and rearing habitat that fish agencies have expended tens of millions of dollars restoring.[8] The Bureau of Reclamation recently recirculated the DEIS/EIR for public comment, presumably in recognition of the fact that current Dam operations need to be modified. However, the Bureau identified two-month gates-in operation as its preferred alternative, a proposal that would continue to have unacceptably high adverse effects on listed salmonids.[9] DFG should require that any

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[8] With regard to predation, the Red Bluff Diversion Dam DEIS/EIR acknowledges that lack of flow below the Dam during gates-in operation allows predators such as Sacramento pikeminnow and striped bass to congregate below the Dam and consume vast amounts of juvenile salmonids. DEIS/EIR, p. 3-15. It also recognizes that predation by avian species may be greater near the Dam than on undammed reaches of the Sacramento River, presumably because of the slackwater conditions and congregating fish caused by lack of flow. *Id.* The U.S. Fish and Wildlife Service has concluded that predation alone causes the death of up to 42% of migrating steelhead and more than 50% of Chinook salmon below the Dam. DEIS/EIR, p. B.-7.

[9] The Red Bluff Diversion Dam DEIS/EIR acknowledges that the following percentages of listed fish and other salmonids would continue to be impacted by gates-in Dam operations during the months of July, August, and early September:

CESA-compliant plan include year-round gates-out operation of Red Bluff Diversion Dam.

B. Delta Habitat Restoration Measures are Required by CESA

The Delta is one of the most highly modified aquatic ecosystems in the nation. Those changes have had significant adverse impacts on both listed salmon species and smelt. The provisions of CESA suggest that DFG should require DWR to implement, in an expedient manner, an ambitious set of habitat restoration measures in the Delta, designed to minimize and mitigate the impacts of the projects on state-listed species.

The operations of the SWP and CVP have a significant impact on the suitability of habitat in the Delta. The POD investigations have revealed, for example, that the lack of suitable habitat has resulted in the concentration of smelt near the Delta pumps. The lack of adequate food supplies, in part a likely indirect impact of the projects, also threatens the smelt. The operations of the cross channel gates divert salmon smolts into the Central Delta, which provides poorer habitat and likely increases mortality rates.

A wide range of Delta restoration actions have been investigated through the CALFED Program and other efforts. Recently, the PPIC report discussed the potential fisheries benefits of Delta restoration actions[10]. In addition, the Action Plan includes a significant discussion of potential food web and habitat restoration measures[11]. For example, the construction of fish passage facilities at the Fremont Weir and the provision of adequate flows into the Yolo Bypass could allow downstream migrating salmon to avoid the Delta cross-channel, thus reducing the impacts of the pumps. In addition, the restoration of habitat in the Yolo Bypass, Cache Slough, Sherman Island, Decker Island, Dutch Slough and the Suisun Marsh could provide rearing benefits for salmon and food chain benefits for Delta smelt. Cache Slough and the Suisun Marsh are known spawning area for Delta smelt.

Winter-run Chinook adults:	3% of the total run
Winter-run Chinook juveniles:	39% of the total run
Steelhead adults:	16% of the total run
Steelhead juveniles:	26% of the total run
Fall-run Chinook adults:	25% of the total run
Fall-run Chinook juveniles:	3% of the total run
Late fall-run Chinook juveniles:	27% of the total run
Spring-run Chinook adults:	11% of the total run
Green Sturgeon juveniles:	61% of the total run

DEIS/EIR, pp. B-6 to B-16. The extent of these impacts is simply unacceptable for fish facing extinction.

[10] PPIC, page 77

[11] Action Plan, page 59.

The Action Plan addresses the potential benefits of these actions, however, it contains little, if any, commitment to implement any of these projects. In addition, in some areas, such as the discussion of Suisun Marsh, we believe that more extensive habitat restoration measures should be considered. The provisions of CESA require a stronger commitment to implementation than is contained in the Action Plan.

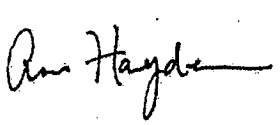
IV. THE BAY-DELTA CONSERVATION PLAN DOES NOT MEET CESA REQUIREMENTS

The goal of the Bay-Delta Conservation Plan (BDCP) is to develop a plan that allows water operations to proceed in a way that is compatible with the recovery of key species that live in or migrate through the Bay-Delta by implementing a robust set of conservation actions. While the BDCP is intended to comply with all aspects of the State and Federal Endangered Species Act's through the development of conservation measures and a comprehensive strategy, the development of the plan is nowhere near being ready so as to have any relevance to the immediate need for CESA compliance. At best, the plan will be completed at the end of 2008 and will still require the development and certification of an EIR/S which will involve additional time to complete. We believe that it is likely that it will require significantly more time than assumed in this timeline for the BDCP to produce a plan

It is also important to note that while the goal of the BDCP is to meet the recovery standard of the Natural Communities Conservation Planning Act, this effort has not yet committed to meet the recovery requirement of this act. In addition, the voluntary nature of the process allows for any applicant to withdraw from the process at any time and request a much less rigorous standard for compliance. It is quite possible that at the end of the day the final plan might not include much more, in terms of protective measures, than what is currently in place. Therefore, there is no basis for using the BDCP, which is far from completion and has an uncertain conclusion, as justification for granting a Consistency Determination.

We look forward to discussing these issues with you further. Please feel free to contact any of the organizations identified below for more information.

Sincerely,



Barry Nelson
Senior Policy Analyst
Natural Resources Defense Council

Ann Hayden
Senior Water Resource Analyst
Environmental Defense

Gary Bobker
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The Bay Institute

Jonas Minton
Water Policy Advisor
Planning and Conservation League

Bill Jennings
Executive Director
California Sportfishing Protection Alliance

Cc: Senate President pro tem Don Perata
Senator Mike Machado
Senator Joe Simitian
Senator Daryl Steinberg
Assemblywoman Lois Wolk
Assemblywoman Loni Hancock
Assemblyman Jared Huffman
Susan Kennedy, Chief of Staff
Mike Chrisman, Resources Secretary
Lester Snow, Department of Water Resources

California Department of Water Resources
SWP Reliability Report-Attn: Johnnie Young-Craig
P.O. box 042836
Sacramento, CA 94236-0001

December 19, 2005

attachment #4

Subject: The State Water Project Reliability Report 20005—Draft

Dear Sirs:

The report informs us that it is an update to the 2002 edition of the report of the same name. The foreword states that DWR will update this information every 2 years. However, the Department of Water Resources is derelict in not acknowledging that this report is a requirement of the amendments to the SWP contracts that was agreed to in the settlement negotiations pursuant to the Monterey litigation.

Purpose

The report is not simply information to help the contractors understand to what degree they can rely on SWP deliveries, but in fact is an essential requirement stemming from the need to eliminate "paper water" from the contracts. The Appellate Court was clear on the problems in planning that proceeded from the previous interpretations allowed by DWR that in effect created the notion of "paper water." In the settlement negotiations it was made clear that a well documented and unambiguous report of delivery reliability was essential to the elimination of "paper water." Accordingly, this report must be reviewed with that primary objective in mind.

Does the report fulfill that purpose? Its self-defined scope certainly allows for that possibility, but without serious calibrations of the main analytic tool, CALSIM II, used to perform the analysis, it is doubtful that it can. This deficiency has been pointed out many times over the past several years and DWR has still failed to come to grips with it. Their limited study, whose results are summarized in the draft, do little to meet the requirements of a legitimate calibration. Calibration, properly done, allows the program developers to assure that all elements of the computer program work properly. In the case of CALSIM II the calibration will show from where in the operational regimen of the SWP the increased amounts of water it predicts will materialize. Even the Scientific Peer Review Committee stated as much; they noted without a proper calibration there is no assurance that the results that are calculated from an optimization routine are a real solution. They must be shown to conform to realistic operations that are known to be feasible. No where in the report is this demonstrated or even hinted at.

Previously Noted Deficiencies

The lack of calibration and other deficiencies have been made known the DWR in formal comments on the 2002 draft. On reading this draft there seems to be no acknowledgement that any of these deficiencies have been addressed. The list of these previous deficiencies is highlighted below.

1.) The frequency diagrams are without statistical merit and therefore cannot be used to provide estimates of "reliability."

2.) The draft continually refers to CALSIM II as a "simulation." Until CALSIM II has been calibrated to show that it conforms to a real and feasible operational regimen, its results cannot be interpreted as though it is a simulation. Even then, its computerized configuration is not even close to what is ordinarily referred to as "simulation." CALSIM II is an optimization model in which the objective function is to maximize exports of water from the Delta given certain constraints. In typical optimization models not all solutions are feasible. Only calibration can establish that possibility. This model does not meet that criterion.

3.) The model makes certain assumptions about the individual contractors' demand for SWP deliveries. Those demand functions have not been vetted against the realistic capabilities of each contractor to take SWP water. In one case the assumption is factually wrong- San Luis Obispo County physically cannot take its full Table A amount of 25,00 acre feet because it is limited by physical capacity of the SWP pipeline to only 4800 acre-feet. Nonetheless, the model assumes that SLO County will take 25,000 acre-feet when it is available at the Delta. Also there are some contractors that are unable to take their full Table A amount simply because they don't have the proper amount of equalizing storage to take the water when the SWP says it is available. The demand functions have not taken these and many other considerations into account. Because the model is an optimization against these demand functions the results cannot be taken at face value until the demand functions have been made realistic in terms of the requirements of the individual contractors.

4.) The report uses a definition of reliability that follows from their construct -ion of the frequency charts they use to summarize the results. When they state for example that the project can deliver 73% reliability, that is an incorrect interpretation of the data in the chart. In fact, the point at which 73% of the Table A water is delivered is actually the 50% point in the frequency chart. The correct statement would be: The project can deliver 73% of the water 50% of the time. However, this is not quite true either because the frequency charts are not statistically valid and insufficient to support an estimate of delivery reliability.

Additional Deficiencies

There are also some additional deficiencies that have since been revealed through careful studies of the CALSIM II model. These have to do with the assumptions on constraints and some fundamental errors in the statistical basis of the model's inputs.

The model exercises for this report assume that SWRCB rules that operate to constrain export pumping will continue unchanged into the future. If the model results showed that future export pumping would continue at about the same level, that may perhaps be a defensible assumption. However, we have the case where the model results show that on average future export pumping will be 50% greater than the recent historical average under most all anticipated hydrologic conditions. Given that result it would seem prudent to examine to what degree SWRCB rules might be modified in anticipation of the environmental damage to be expected with such an increase in export pumping. The model does not do that. In fact, before these results can be used by anyone, the model's calculations should be explored to discover where and to what degree existing historic pumping regimens are expected to change. After all, the existing rules were developed in response to concerns with the operational problems that were demonstrated along the way during historic pumping. The rules certainly cannot be interpreted as definitive statements on what is acceptable for the Delta environment irrespective of the levels of export in the future.

The model also uses a sub-model to calculate the movement of the X 2 salinity threshold in the Delta as a function of hydrologic conditions. Unbelievably the sub-model calculational routine does not include the level of pumping. It is difficult to believe that the movement of the salinity threshold is independent of export pumping. Furthermore, given that CALSIM II predicts a 50% increase in exports over historic levels it would seem prudent to examine whether this simple routine is really applicable at that higher level. The research that went into the development of this calculational routine should be peer reviewed. The same may be said with the entire modeling of cross Delta transport calculations.

Perhaps the greatest problem with CALSIM II is its total disregard for proper statistical analysis in the development of the model. It is easy to verify that the input hydrology to the model represents a complex statistical distribution. In fact, it is what is referred to by statisticians as "bi-modal" meaning there are two main modes. One significant consequence of this feature is that the grand average of the total 73 year record is a very unlikely occurrence. All references in the report to average deliveries over 73 years are totally misleading.

The two modes clearly depict a collection of dry years and another of wet years. There are slightly more cases of dry years than wet ones although for practical purposes they are roughly equal. It is also the case that except for droughts there is virtually no serial correlation year-to-year. This means that a wet year may be followed with equal likelihood by either a dry or wet year. The fundamental problem that SWP operators must continually face is under what conditions is it prudent to pump given uncertainty in what kind of year the project will face. It is a classic operations research problem and involves tradeoffs between the objective of pumping water and the risk that too much will be taken. This operational problem is faced at the beginning of every water year beginning in the fall. A careful study of historic input flows from the Sacramento River in the fall and winter shows that it may be difficult to establish until late in January if the water year will likely be wet so as to allow higher levels of pumping. But a careful examination of SWP pumping capacity shows that the pumps must run at nearly maximum capacity for most of the year if export flows near 4 MAF are to be realized. Clearly, if the 73 average predicted by this model is near 4 MAF then we must assume that heavy pumping is

allowed during the fall and winter months before it is known that the year will indeed be wet. How is this reconciled with prudence and so call risk avoidance?

Because the model incorrectly deals with the statistical nature of the input hydrology it also includes some totally improper inputs. The model relies on a "water year index" which is a convolution of the spring and fall/winter runoffs across years. The affect is to produce an index which is uni-modal in contrast to the bi-modal hydrologic input. Because there is no significant year-to-year correlation in runoff, this convolution is without scientific merit and totally distorts the basic operational decision problem so that it no longer represents any reality. Furthermore, this water year index is further convoluted to a "water year type" designator that is used to establish Delta export/inflow ratios that ostensibly are used to protect the Delta environment.

The "water year type" is the index that is used in the CALSIM II model to establish what the required outflow in the Delta must be to satisfy the SWRCB rules. It is used in the model by a "lookup table" that predetermines the water year before it is fully developed. It does this by combining the previous spring's runoff with the current fall and/or winter runoff to decide whether the coming water year is going to be wet or dry. Needless to say, the statistical nature of the runoff record defies predicting what the upcoming water year will be. But by this simple mechanism the model is given fore knowledge of conditions before they are experienced. This departs radically from any notion of simulation. The convolution giving rise to this "water year type" has no demonstrable logical analysis for its existence. Clearly, the CALSIM II model cannot be taken as a valid model until some of these logical flaws are explained or corrected. By extension, the Reliability Report is without any scientific merit and is virtually useless for the purposes stated.

Additional Inconsistencies

There are additional problems that deserve explanation beyond what is stated in the Reliability Report. When one compares the set of tables documenting the past 10 years of deliveries to the various contractors and compares them to the same years reported in the 2002/2003 version there are some significant changes. Out of the ten years only one of the years appears to be the same in the two volumes. Most of the changes in deliveries seem to occur in the values reported for Kern Co. and Castaic Lake Water Agency. The latest report should explain these differences.

Sincerely,

Arve R. Sjovold

Plaintiff CPA Representative
In the Monterey Settlement
Negotiations

Plaintiff CPA Representative
To Monterey ++ EIR Comm.

ADDITIONAL DATA ON
OROVILLE STORAGE
1996-2004

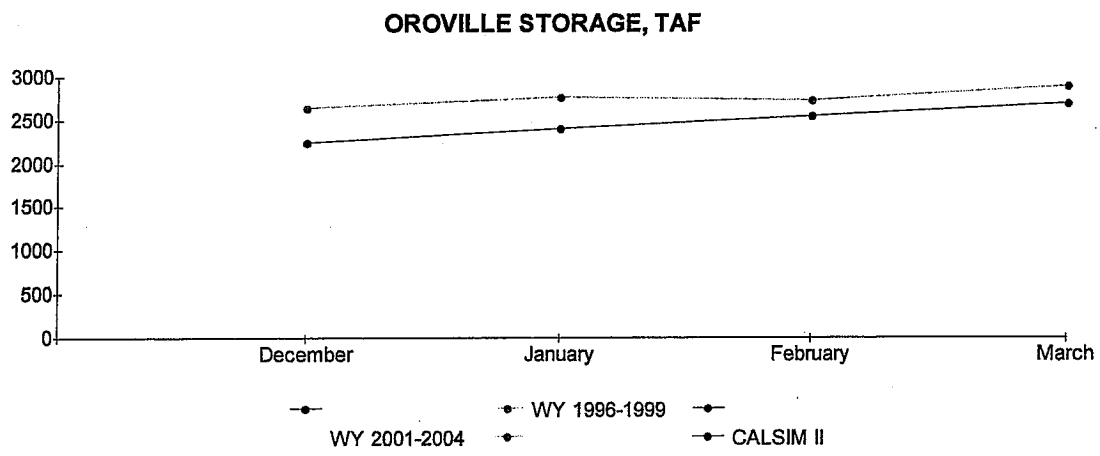
By: Arve R. Sjovold
October 8, 2006

As part of my investigation on SWP pumping from the Delta and releases from Oroville, I also tabulated the corresponding data for Oroville storage. I divided the period into before water-year 2000 and after. This provides two sets to distinguish the changes in operations as a result of the new pumping regimen documented previously. I left out the year 2000 data as I considered it a transition year between the two regimens.

The results are presented in the table below and a corresponding chart. I plot the averages storage levels for the two periods, 1996-1999 and 2001-2004, for the months of December, January, February, and March. Each value represents the average of the four period designated in the column head. A third entry is the estimates provide by the CALSIM II model as reported in a recent draft report from DWR.

I don't know what level is called for by their operational guidelines or any fishery constraints that may apply in these months. However, it is clear that to support the new regimen, it appears that Oroville storage levels will be systematically lower with the new regimen than before. It is also noteworthy that the new regimen levels are systematically lower than the CALSIM II prediction. This may be important to the FERC licensing process now going on.

Month	WY 1996-1999	WY 2001-2004	CALSIM II
December	2636	1798	2250
January	2758	2067	2400
February	2728	2271	2550
March	2886	2541	2700


OROVILLE STORAGE, TAF
3000
2500
2000
1500
1000
500
0
December
January
February
March
WY 1996-1999
WY 2001-2004
CALSIM II

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Gary Patton
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PLANNING AND CONSERVATION LEAGUE

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December 22, 2005

Kathy Kelly
California Department of Water Resources
Bay Delta Office Chief
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Sacramento, CA 95814

attachment #5

California Department of Water Resources
SWP Delivery Reliability Report – Attn: Johnnie Young-Craig
P.O. Box 942836
Sacramento, CA 94236-0001

via facsimile to: (916) 653-6077
via email to: Comments-on-2005DRR@water.ca.gov

Re: Comments on Public Review Draft of the State Water Project Delivery Reliability Report 2005

Ms. Kelly:

The Planning and Conservation League (PCL), a strong advocate for accurate and realistic water supply planning, submits the following comments on DWR's Public Review Draft of the State Water Project Delivery Reliability Report (Draft Reliability Report). As one of the signatories to the court-approved settlement agreement requiring DWR to prepare these biennial reliability reports, PCL seeks to ensure that the final report lives up to the rigorous reporting requirements specified in that agreement. Serious deficiencies are present in the Draft Report that, if left uncorrected, would dangerously overestimate DWR's future ability to deliver water and compound the risk that local planning decisions will be predicated on "paper" rather than deliverable water.

The Reliability Report Should Accurately Disclose its Foundation in the Settlement Agreement and the State Water Project Contracts

The present Draft fails to inform local decision-makers and the public of the context and history behind DWR's reporting requirement. DWR's legal duty to prepare biennial reliability reports arises from the court-approved settlement agreement executed by PCL, DWR, state water contractors and other entities in the wake of the Third District Court of Appeal's ruling in the "Monterey Amendments" case, *Planning & Conservation League v. Department of Water Resources* (2000) 83 Cal. App. 4th 892.

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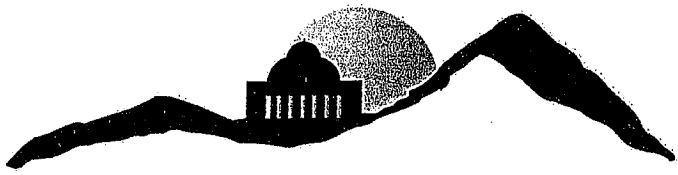

PLANNING AND CONSERVATION LEAGUE

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Los Angeles

In *Planning & Conservation League*, the decision invalidating the Monterey Amendments EIR, the court bluntly addressed the "huge gap" between the 4.23 million acre-feet of SWP entitlements referenced in Table A of the SWP contracts and the half or less of that amount the state can reliably deliver. Recognizing the practical consequences of paper water for local development decisions, that court vindicated "the commonsense notion that land use decisions are predicated at some level on assumptions about available water supply. The Court also recognized that reliance on "paper water in local development decisions can produce excessive groundwater pumping and a host of other detrimental environmental consequences. " (83 Cal. App. 4th at p. 915.)

In the settlement decision following that ruling, DWR expressly agreed to add a rigorous new set of reporting requirements. In a new provision (Article 58) of the SWP contract, DWR committed to the following:

> 1.Commencing in 2003, and every two years thereafter, the Department Water of Resources (DWR) shall prepare and deliver to all State Water Project (SWP) contractors, all city and county planning departments, and all regional and metropolitan planning departments within the project service area a report which accurately sets forth, under a range of hydrologic conditions, the then existing overall delivery capability of the project facilities and the allocation of that capacity to each contractor. The range of hydrologic conditions shall include the historic extended dry cycle and long-term average. The biennial report shall also disclose, for each of the ten years immediately preceding the report, the total amount of project water delivered and the amount of project water delivered to each contractor. The information presented in each report shall be presented in a manner readily understandable by the public. (Settlement Agreement Attachment B)

The Settlement Agreement further states:

> 3. DWR shall provide assistance to enable all Municipal and Industrial Contractors to provide complete and accurate information to relevant land-use planning agencies to assure that local land-use decisions reflect accurate information on the availability of water from state, local, and other sources. (Settlement Agreement Attachment B)

The Draft Reliability Report does not fulfill these requirements. As detailed in the remaining sections of these comments, the Draft omits important information and misinterprets data, which would mislead both the public and local water agencies. Accordingly, it lacks the accuracy that the settlement agreement requires. In order to help DWR meet the commitments made under the settlement agreement, we submit the following comments for inclusion in the final 2005 Reliability Report.

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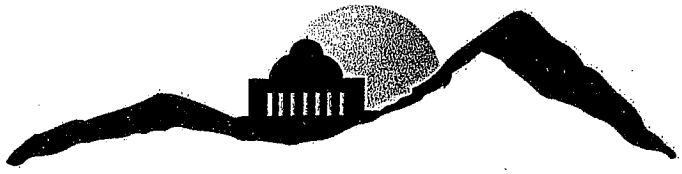

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Excerpts of the Reliability Report should not have been privately shared with the State Water Contractors, but denied to PCL and the public

We are aware that DWR provided an earlier draft chapter of the Draft Reliability Report to State Water Project contractors in May 2005 ("Excerpts from Working Draft 2005 SWP Delivery Reliability Report") and further recommended that local agencies incorporate information provided in that draft chapter in their Urban Water Management Plans (UWMPs). Castaic Lake Water Agency has acknowledged relying on that document in reviewing other projects, and other contractors may have done so as well. However, DWR did not provide that draft chapter to PCL or the public, even though PCL staff requested the opportunity to review the draft. After followup requests, we were informed that the draft chapter would be posted to a web page for contractor announcements. There was no public announcement informing interested parties of the availability of the draft chapter.

DWR's decision to circulate part of the report to the contractors, while denying that same document to PCL and members of the public, represents an unfortunate throwback to the defective process singled out for criticism in *Planning and Conservation League*, where the court took notice of the interested parties and members of the public who were "not invited to the table." (83 Cal. App. 4th at 905.)

The draft and final Reliability Reports should be available to the public prior to deadlines for local agency Urban Water Management Plans

The most important purpose of the Reliability Report is to provide local water agencies and the public with accurate and realistic information on the reliability of SWP deliveries. Those local agencies should be able to use that information in planning documents and to inform land use decisions. Unfortunately, the timing of this report significantly compromises its utility. DWR did not release its draft to the public until just weeks prior to the state mandated deadline for local water agencies to complete and submit their 2005 Urban Water Management Plans.

DWR's decision to provide a single draft chapter prior to release of the full draft significantly compromises the information now included in many UWMPs. Without the complete report and the benefit of public review, decision-makers, planners and the public were denied the opportunity to evaluate and confirm the credibility of the information included in the draft chapter and now included in the UWMPs. Releasing the draft chapter and significantly delaying the release of this report is functionally equivalent to eliminating public oversight and transparency.

Water supply information from one chapter of a draft report also does not provide an adequate level of certainty or rigorous review required to determine the reliability of future water supplies for millions of Californians. To avoid damaging that review, water agencies and the public were supposed to have the complete final report, not just a preliminary part of it.

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DWR must ensure that in the future, the public will have ample opportunity to review and comment on Draft Reliability Reports, and that those public comments will be appropriately responded to and incorporated into vetted and substantiated final future reports well before Urban Water Management Plans are due to the State.

The Reliability Report should include DWR's analysis of SWP reliability under anticipated effects of climate change.

The 2005 Draft Reliability Report recognizes that a primary factor in determining reliability of SWP supplies is the availability of water in source areas. Yet the Draft Report fails to discuss and incorporate known and recognized information regarding the substantial adverse impacts climate change will have upon California's water supply. This omission is particularly troubling because DWR previously committed to including such information.

In 2002 DWR's first Reliability Report recognized that climate change could significantly alter availability of water in source areas. The 2002 report stated that information on climate change impacts to California was being developed in the California Water Plan Update process, and that such information would be incorporated into the 2005 reliability report. The California Water Plan Update 2005 is now nearly complete, and it contains information on climate change. The April 7, 2005 draft of the Water Plan Update states:

> California's relies on snowpack as its largest means of annual water storage. Runoff from the Sierra Nevada mountains during April through July of each year averages 14 million acre-feet and comes primarily from snowmelt. Computer modeling of global climate change scenarios predict significant future reductions in the Sierra snowpack. A reduced snowpack will reduce the total water storage for the state. Figure 4-7 (Model simulation of potential changes in snowpack during the 21st Century) shows a 52 percent reduction in the annual April through July runoff for a 2.1 degree C (3.8 F) of warming, well within the 1.4 to 5.8 degree C (2.5–10.4 F) range predicted by global climate models for this century.
>
> Changes in the timing of snowfall and snowmelt, as a result of climate change, may make it more difficult to refill reservoir flood control space during late spring and early summer, potentially reducing the amount of surface water available during the dry season. Changes in reservoir levels also affect lake recreation, hydroelectric power production, and fish habitat by altering water temperatures and quality. Reductions in snowpack may require changes in the operation of California's water systems and infrastructure, and increase the value of additional flood control space in reservoirs. (Public Review Draft California Water Plan Update, April 7, 2005, Vol. 4, page 4-27)

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Despite the commitments made in the 2002 Reliability Report, this information is not included in the recent draft of the 2005 Delivery Reliability Report.

In addition, the Draft Reliability Report misleads readers by suggesting that information on climate change impacts in California is not available. Since the release of the Draft Reliability Report 2002, a large amount of analysis on potential climate change impacts on water management in California has been published. Yet, the Draft Report 2005 states:

> The studies do not incorporate any modifications to account for changes related to climate change or assess the risk of future seismic or flooding events significantly disrupting SWP deliveries. As tools are developed to address these risks and the resulting studies become available, the information will be incorporated into the assessment of SWP delivery reliability. The results of the CalSim-II studies conducted for this update to *The State Water Project Delivery Reliability Report 2002* (DWR 2003b) represent the best available assessment of the delivery capability of the SWP. (Draft Reliability Report page 17)

However, estimates of the deliveries from the SWP under climate change conditions have been modeled and analyzed. The California Energy Commission recently completed such an analysis in their report, "Predictions of Climate Change Impacts on California Water Resources Using CalSim-II: A Technical Note" (CEC report).

In contrast to the statement included in the Draft Reliability Report, the CEC report provides assessments of SWP delivery capability under several probable climate change scenarios. This work was prepared in response to Executive Order S-3-05 issued by Governor Schwarzenegger, which called for a report on the impacts to California of global warming, including impacts to water supply, public health, agriculture, the coastline, and forestry.

It includes analysis carried out using CalSim-II, some of it performed by DWR staff.
It is disappointing that it took the initiative of the Energy Commission to generate climate change scenarios that PCL has been requesting of DWR for over two years. Moreover, DWR cannot credibly represent that such studies are impossible even after they become publicly available. To claim otherwise would fatally compromise the commitment to accuracy that is the hallmark of DWR's reporting requirement.

The figures below from the CEC Report show that under climate change hydrologies, SWP deliveries at 75% reliability could be as much as 1.9 million acre feet less than the base condition.

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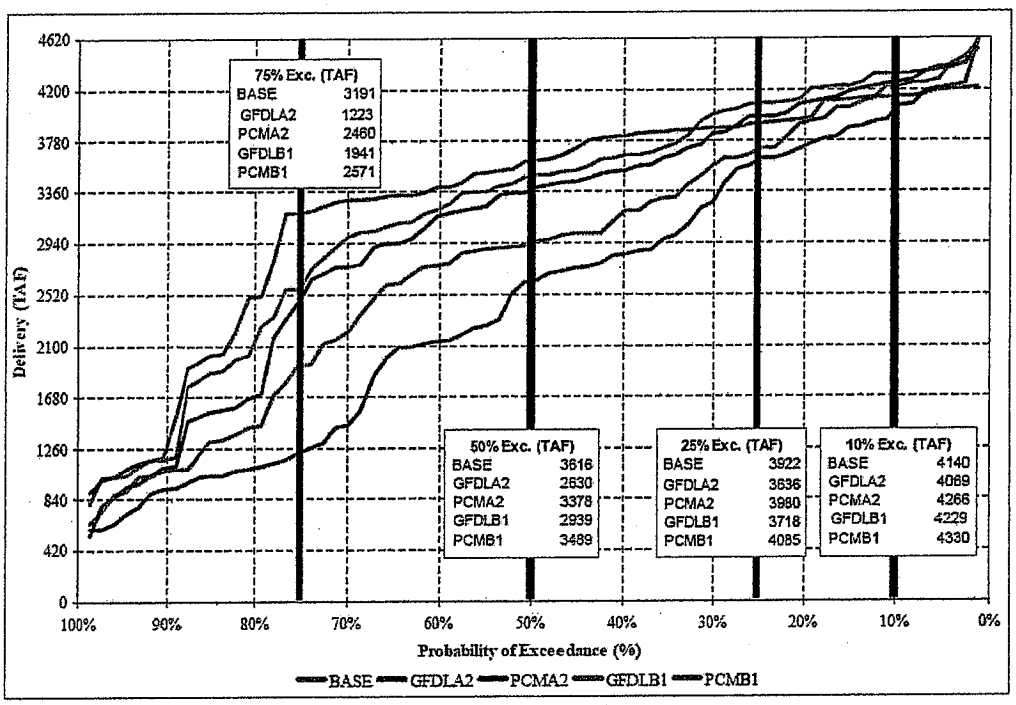

Figure 7. Exceedance probability plot of SWP Annual Deliveries under climate change scenarios PCM B1-A2 and GFDL B1-A2 for 2070-2099

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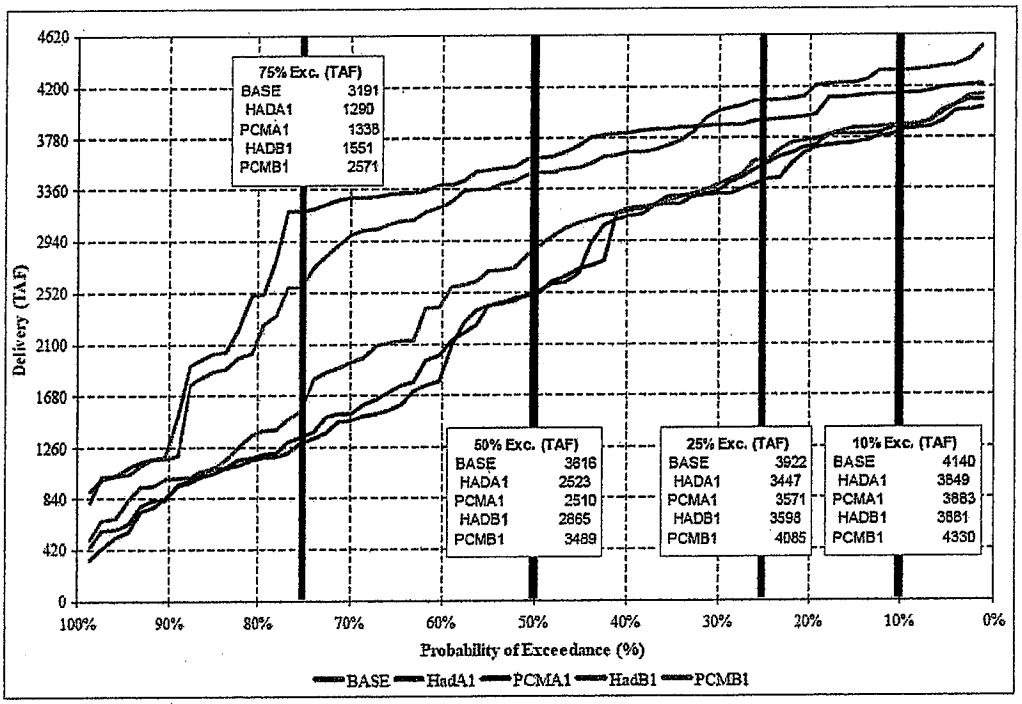

Figure 8. Exceedance probability plot of SWP Annual Deliveries under climate change scenarios PCM B1-A1 and HadCM3 B1-A1 for 2070-2099

(California Energy Commission, draft Predictions of Climate Change Impacts on California Water Resources Using CalSim-II: A Technical Note, December 2005 page 14 & 15 http://www.energy.ca.gov/2005publications/CEC-500-2005-200/CEC-500-2005-200-SD.PDF)

The CEC report concluded that modeling, "results show great negative impacts on California hydrology and water resources associated with most of climate change scenarios analyzed (only one scenario PCM run under B1 emission scenarios show just mild negative impacts)." (page 4)

This information demonstrates the range of outcomes that water managers must be prepared to address. This important assessment of the delivery capability of the SWP should be included in the Draft Reliability Report.

We also understand that DWR may have done its own analysis of the impacts of climate change on SWP deliveries. On the official State of California Climate Change Portal (http://www.climatechange.ca.gov/climate_action_team/reports/index.html) there is a reference to a study done by DWR. However unlike all of the other references, no results are included. The Reliability Report should include the results of DWR's own analysis.

Omission of this information prevents planners and decision makers from preparing for the inevitable implications for their water supplies. If the CEC already is predicting that water

availability, and thus SWP deliveries, will be substantially reduced in the near future, water planners must adjust to that reality. DWR must address this problem, and will do California an enormous disservice if it continues to pretend that this problem does not exist.

Information in the Reliability Report will be used by local planners to make infrastructure investments and development decisions. The decisions made today about where to place infrastructure and where to approve development are long term commitments that will have impacts for hundreds of years into the future.

For instance, local decision-makers may chose not to place purple pipe in new development on the basis of assumed high level of delivery reliability from the SWP. Instead, decision-makers could choose to invest in new infrastructure to provide traditional supplies, including SWP supplies to new development. Once development is approved, the local area has foregone the opportunity to increase water supply reliability through use of recycled water. Should SWP supplies become significantly lower than predicted in the Reliability Report due to foreseeable impacts of climate change, significant local and statewide investments in infrastructure and housing would be stranded.

If local decisions are predicated on information from DWR that does not fully acknowledge potential constraints on DWR deliveries, they run the risk of producing excessive groundwater pumping and a host of other detrimental environmental consequences " (See *Planning and Conservation League*, 83 Cal. App. 4th at p. 915.)]

The long term nature and the resulting implications for the future of local areas as well as California as a whole, demand that the Reliability Report provide accurate, realistic information that fully discloses foreseeable uncertainty and risks.

The Report's unreliability also creates financial risks for the state. In many cases bonds will be committed to infrastructure built on expectations generated or encouraged by the Reliability Report. As with any financial investment, the risks associated with these investments must be fully disclosed to those who buy the bonds, those who approved the bonds, and those who invest in that infrastructure or in the developments supported by that infrastructure. As the state has learned in the past with levee liability, there is a potential risk that the State may be held accountable for decisions and investments made by others on the basis of false interpretation of the State's ability to protect and guarantee those investments.

The Reliability Report should include risk analysis and impacts from catastrophic failure in the Bay Delta Estuary from earthquake or flood

The Draft Reliability Report correctly identifies the availability and means of conveyance as a primary factor in determining reliability of SWP supplies. However, like climate change impacts, the Draft Report fails to include analysis or discussion of serious and eminent risks to the Bay Delta

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Estuary, an essential component of the SWP conveyance system. Significant risks to the ability of the SWP to export water from the Bay Delta Estuary are posed by the vulnerability of levees to flood, sea level rise and earthquake, as well as environmental degradation and continued declines of important fish species.

Dr. Jeffery Mount from the University of California, Davis, recently completed a risk analysis estimating that there is a 64 percent probability that the Bay Delta Estuary will experience abrupt changes resulting from flooding or seismic activity within the next fifty years. These changes would permanently alter the hydrology, water quality and ecosystem of the Estuary. Furthermore, Dr. Mount found that there is no institutional capacity to address these permanent changes. (Subsidence, Seismicity and Sea Level Rise: Hell AND High Water in the Delta; presented by Dr. Jeffery Mount to the California Bay-Delta Authority October 14, 2004. http://calwater.ca.gov/CBDA/AgendaItems_10-13-14-04/Presentation/Item_13_6_Subsidence_Seismicity_Sea_Level_Rise.pdf)

In recent testimony to a joint committee of the California Legislature, Lester Snow, Director of DWR, outlined the serious risks to SWP water supply availability associated with Bay Delta levee failure. In his presentation, "How a Delta Earthquake Could Devastate California's Economy," Director Snow stated that extended impacts to water availability would include:

- Using most optimistic projection, levee repairs will require at least 15 months. More realistically, the repairs will take much longer.
- Southern California water agencies are drawing from reserves. Some will last up to 36 months; others will go dry sooner.
- Extreme water conservation measures enacted
- Ground water basins drawn dangerously down – may lead to contamination
- Water conservation and transfer programs enacted

(Slide 16 of Lester Snow's presentation to the joint legislative committee, November 1, 2005 http://www.publicaffairs.water.ca.gov/newsreleases/2005/11-01-05DeltaEarthquake.pdf)

Director Snow further indicated that recovery of the conveyance through the Delta could be abandoned. (Slide 19 of Lester Snow's presentation). Director Snow told the Legislature that "... we also need to recognize the Statewide impacts ...if Delta water supplies are reduced or eliminated as a result of a catastrophic failure of our levee system." (Quote taken from DWR Press Release, November 1, 2005, http://www.publicaffairs.water.ca.gov/newsreleases/2005/11-01-05flood.cfm)

Accordingly, the Reliability Report should incorporate Director Snow's recommendation to recognize the risk to SWP reliability from flood, sea level rise and earthquake.

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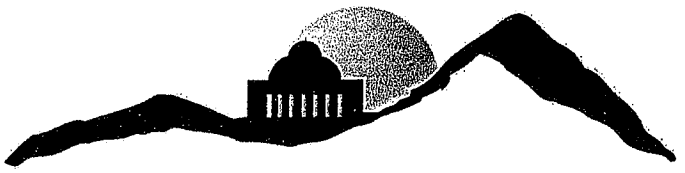

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In addition to vulnerable levees, ecosystem degradation poses a significant risk to the ability to convey SWP water reliably through the Bay Delta Estuary. Recently, data from the Department of Fish & Game's Fall Mid Water Trawl signaled that there is a serious ecosystem collapse in the Estuary, with four important pelagic fish populations at historic lows, including the California and Federally Endangered Species Act listed Delta Smelt.

In response, many agencies, including DWR are participating in an emergency science review called the 'Pelagic Organism Decline' (POD) investigation. The most recent report from the POD investigations indicates that increased exports, which increase fish entrainment and decrease available habitat, may be a primary contributor to the fisheries declines ("Interagency Ecological Program Synthesis of 2005 Work to Evaluate the Pelagic Organism Decline (POD) in the Upper San Francisco Estuary," November 2005 http://science.calwater.ca.gov/pdf/workshops/IEP_POD_2005WorkSynthesis-draft_111405.pdf).

The final Reliability Report should acknowledge the current pelagic organism decline and disclose the possibility that decreases in exports may be necessary in order to reverse those declines. Lastly, while the pelagic species decline currently is the most salient of the Bay-Delta Estuary's environmental problems, it is not the only problem that might compel delivery reductions. Bay-Delta water currently does not meet federal or state water quality standards, and many other species are listed as threatened or endangered. The final Reliability Report should acknowledge that fixing these other environmental problems also may require export reductions.

The Reliability Report should evaluate variable levels of demand, utilizing demand modeled in the Draft California Water Plan Update 2005

The Draft Reliability Report identifies the level and pattern of water demand in the delivery service area as the third primary component in determining SWP reliability. However, the Draft Reliability Report does not examine a significantly varied range of possible demand scenarios for the future. That omission is important, for such analysis would likely show that reliability is inversely proportional to California's overall level of demand.

Recent work completed by DWR for the California Water Plan provides a range of demand scenarios that should be included in the Reliability Report. The California Water Plan Update 2005 identifies three plausible demand scenarios: current trends continued; less resource intensive; and more resource intensive. Two of these three scenarios demonstrate that it is plausible that in 2030 California water demands will *decrease*, even with an expected 12 million more residents. The greatest decreases in water demands in every scenario occur in the SWP service area of Tulare Lake.

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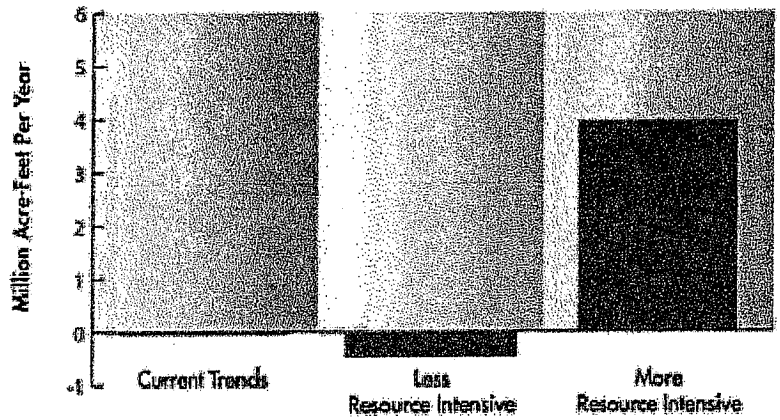
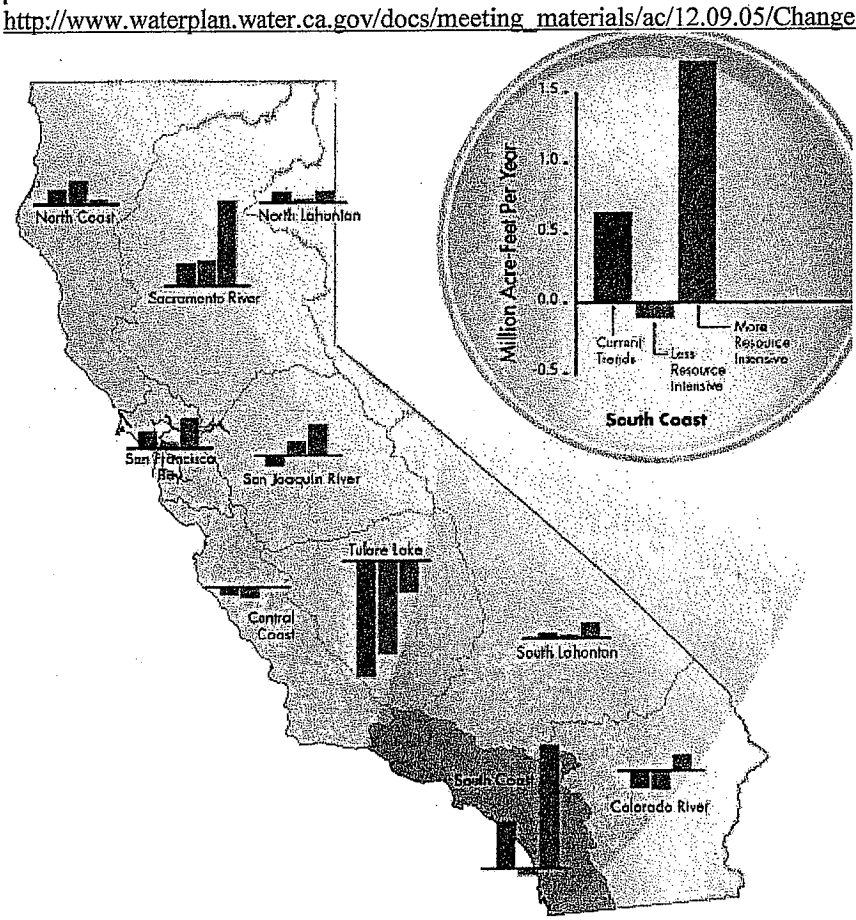
Figure 4-2 Net changes statewide in average-year water demand for baseline scenarios, 2000–2030



An additional 1 maf to 2 maf per year (not shown in the figure) is needed for all scenarios to eliminate ground-water overdraft statewide.

Water demands may change between 2000 and 2030 for average water conditions. Statewide water demand changes are shown for three baseline scenarios.

http://www.waterplan.water.ca.gov/docs/meeting_materials/ac/12.09.05/Changes_to_PRD_Slides_(12-08-2005).pdf



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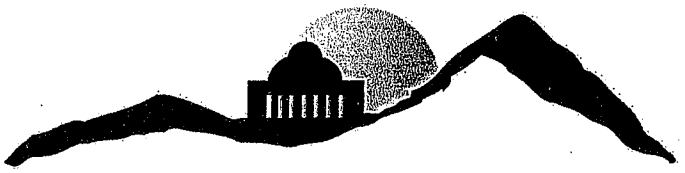

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Recently, the California Court of Appeals determined that state and Federal water agencies erred when they failed to adequately assess a range of reasonable scenarios in the CALFED ROD EIR in part because the environmental document did not include an analysis of reduced pumping from the Bay Delta Estuary (*In Re Bay Delta Programmatic Environmental Impact Report Coordinated Cases* (2005) 133 Cal.App.4th 154). Consistent with this finding, and DWR's recent good work on the State Water Plan Update, the Reliability Report should evaluate reliability under the three demand scenarios presented in the California Water Plan Update.

The Reliability Report should be consistent with operations described in environmental reviews

The Draft Reliability Report assumes that SWP deliveries into the future will be much higher than historic averages. In the past, SWP deliveries have averaged about 2 maf per year, while the Draft Reliability Report proposes that future deliveries will average from 2.8 to 3.1 maf annually. The Draft Reliability Report also assumes that an additional maximum of 1.11 maf of water could be delivered under Article 21.

Because CalSim-II is an optimization model that does not necessarily reflect options available to water operators, it may predict these levels of exports. However, federal and state water quality and endangered species laws and regulations probably would prohibit such high export levels for water quality problems and if species impacts were chronic even at historic levels. In light of the recent pelagic organism declines in the Bay Delta Estuary, it is prudent to ensure the Draft Reliability delivery predictions would not violate conditions of the Federal Clean Water Act, the Federal or California Endangered Species Acts, or any other environmental permit condition, regulation, standard, or law.

In order to ensure that stated water deliveries would be legally feasible, the Reliability Report must explicitly state whether listed export levels are consistent with those modeled in environmental reviews, including the recently issued biological opinions. For instance, the Reliability Report should state whether the Biological Opinions for OCAP in 2004 accounted for impacts to listed species under a modeling scenario that contemplated deliveries of 1.11 million acre feet of Article 21 water.

The Reliability Report should not recommend that water agencies integrate Article 21 as firm annual supplies in planning documents

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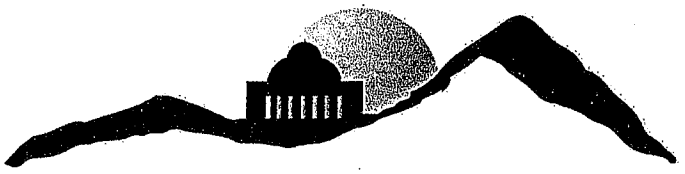

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Article 21 water is by definition interruptible water; indeed, the word "interruptible" replaces the formerly used "surplus" in the Monterey Amendments. It should not be used as the basis for uninterruptible demands. Yet in chapter 6 of the Draft Reliability Report, local agencies are encouraged to include Article 21 water in a table of average annual values.

As DWR is aware, water supplies accounted for in the Urban Water Management Plans become the basis for approval of water supply assessments for new development in California. It is not only imprudent, but would provide institutional cover for unreliable planning, to recommend that local decision-makers approve housing that will be dependent on water that is 'interruptible.'

Article 21 water should be removed from the recommended table of average annual deliveries.

Use of CalSim-II as the sole tool to determine reliability is inappropriate given the following significant and yet to be resolved deficiencies

The lack of calibration and other deficiencies of CalSim-II have been made known the DWR in formal comments on the 2002 Draft by several parties, specifically Arve Sjovold and Dennis O'Conner. In addition, a 2003 expert peer review report documented numerous problems in CalSim II, and concluded that its predictions should be treated as "hypotheses." A. Close et al., A Strategic Review of CalSim II and its User for Water Planning, Management and Operations in California 13 (2003). This Draft has not adequately addressed those deficiencies. Some of these previously-highlighted deficiencies are listed below.

- CalSim-II has not been calibrated or validated
- It is unclear whether CalSim-II incorporates limitations to groundwater use in the Sacramento Valley
- The CalSim-II model should not be used to make absolute predictions, such as those incorporated into the Reliability Report
- CalSim-II does not recognize or report uncertainty

Additionally, CalSim-II may produce results not consistent with reality, replacing the problem of paper water with an even greater problem of 'cyber water.' For example, in 2001, California experienced water supply associated with approximately the 75% exceedence level, and the State Water Project was able to deliver 1,607,570 ac-ft. However, the CalSim-II simulations predicted a 75% exceedence level of supply of roughly 2,500,000 ac-ft (as read from Figure 5.1). In other words, CalSim-II overpredicted deliveries by more than 50%. These discrepancies demonstrate the need to use multiple tools to determine reliability, as well as the need to articulate limitations of this particular model. Similarly, they demonstrate that local agencies will take enormous risks if they approve projects in reliance on CalSim II's predictions that future deliveries will be substantially higher than historic deliveries.

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The Draft Reliability Report attempts to respond to the recent to the recommendations and conclusions from the recent CBDA Peer Review, *A Strategic Review of CalSim II and its Uses for Water Planning, Management, and Operations in Central California* (Close and others 2003).

The Draft Reliability Report states:

> In *Peer Review Response,* DWR and USBR (2004) conclude the concern about overestimations of south-of-Delta deliveries is unwarranted because the 73-year study referenced by the panel is not designed to mimic historical conditions; rather it is intended to determine the reliability of the SWP when the demand equals the maximum Delta Table A amount (4.133 MAF) every year. The results of the referenced study are documented in *The SWP Delivery Reliability Report 2002*
> (DWR 2003b) as study 3 (2021B).
>
> A more appropriate method for assessing the ability of CalSim II to accurately model SWP operations is to compare the historical SWP deliveries with the simulated deliveries of the Historical Operations Study. DWR committed to conducting this study in *The SWP Delivery Reliability Report 2002* (DWR 2003b). The study is documented in the November 2003 Technical Memorandum Report *CalSim-II Simulation of Historical SWP/CVP Operations* (DWR 2003a). The Historical Operations Study is designed to assess CalSim II's ability to mimic historical operations of the SWP. In this study, historical input is used where reliable data are available. In situations where reliable historical record is not readily available, reasonable assumptions and estimates are made. (pages 10 & 11)

Before stating that this approach is the most appropriate response to the Peer Review concerns, DWR should reconvene the panel in order to review whether DWR's response satisfies the concerns raised in the original peer review. To verify that this response appropriately satisfies the concerns raised by that panel.

Additional specific comments on uses of CalSim-II in the Draft Reliability Report 2005 are attached in Appendix A.

Conclusion

PCL hopes that these comments assist DWR in arriving at a final version of the Reliability Report that corrects the serious deficiencies identified in the draft, and provides the

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additional analysis recommended here. Without these additional efforts, the report would not fulfill DWR's responsibilities under the settlement agreement and the Article 58 of the SWP contracts, and would fail to provide local decision-makers with a credible basis to ensure that development decisions are grounded in an accurate assessment of deliverable SWP supply.

Sincerely,

Mindy McIntyre
Water Program Manager
Planning and Conservation League

Cc:
Lester Snow, Director , Department of Water Resources
Antonio Rossmann, Rossmann & Moore, LLP
Roger Moore, Rossmann & Moore, LLP
Dave Owen, Rossmann & Moore, LLP
Senator Kuehl,
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Senator Kehoe
Senator Ducheny
Senator Perata
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APPENDIX A: **Specific comments on uses of CalSim-II in this Draft Reliability Report are highlighted below.**

Page 7: "Whatever assumptions are made, every responsible water delivery reliability analysis should expressly state the assumptions, methods and data used to produce its results. It should also be understood that those numbers depend on, and are no better then, the assumptions upon which they must necessarily rest."

This statement is entirely true. Yet this particular "water delivery reliability analysis" does not measure up to its own standard, because it does not adequately disclose the weaknesses of the key assumptions it makes and the key model upon which it relies. The reliability report should acknowledge that the simulated levels of SWP deliveries reported on the Draft Reliability Report are defined entirely by the explicit and implicit assumptions used in CalSim-II—they are CalSim-II's reliability results and not the results for the physical system itself—and should address the potential weaknesses in the "assumptions, methods and data" used to make those predictions.

Additionally, a statement such as this is so important that it should be made prominently, perhaps in a highlighted text box, rather than at the end of a paragraph in the body of the report.

Page 7: "For example, the demand 30 years ago for the SWP was not as high as it is currently or expected to be in the future. Because the need for SWP water then was relatively low, less water was exported through the SWP during normal and wet times then could have been if the demand had been higher. Simply put, less water was delivered because less water was needed."

The implicit assumption in this statement that there was no logic for contractors to take the water they were entitled to under Table A because 1) they had no need for it at that time, and 2) they had no place to store it for later use. If the assumption is that now and into the future the contractors will want to take delivery of their full Table A amounts—in other words, that circumstances have changed—then one or both of two conditions must be true 1) they need it and/or 2) they can store it. The reliability report should substantiate its reasons for assuming such a change in conditions.

On page 15, the Draft Reliability Report states that studies 4 and 5 were developed in discussions with SWP contractors and stakeholders involved with the development of the analysis associated with the environmental documentation for the Monterey Agreement. What analysis of current or future demand patterns and our available storage capacities is used to justify the assumption of a demand for the full Table A allotments? What are the assumptions about population growth, water use rates, availability of non-SWP supplies and available local storage capacity that lead to the conclusion that contractors will consistently ask for full Table A allotments?

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Page 7: "Conversely, the current or projected delivery capability of the a water project would be less if (1) demand for water from a water project was at its maximum level for many years, (2) no new facilities were built, and (3) the supply of the main sources of water was recently reduced because another entity with a prior water right increased its use of that source."

This statement is unclear and counterintuitive. The Draft Reliability Report often argues that higher levels of demand will increase the delivery capability not decrease it. DWR should clarify the point it is trying to make here or eliminate this statement altogether.

Page 8: "In the 2002 Reliability Report, the Department committed to conducting a comprehensive sensitivity analysis for assumptions contained in the CalSim-II model studies. This analysis is complete."

While this analysis is reported on in the Draft Reliability Report, DWR has made no attempt to use the results of that analysis to comment on the results of the CalSim-II modeling conducted for the reliability investigation. This seems to defeat the purpose of conducting and reporting on the sensitivity analysis. An attempt to consider the implications of the sensitivity analysis is included later in these comments.

Page 11: "The simulated deliveries in Figure 3-1 were adjusted for any differences between the historical and simulated carry-over storage in the SWP system reservoirs, Lake Oroville and SWP's portion of San Luis Reservoir."
Page 74 "(in Appendix E dealing with the Historical SWP/CVP Operations Simulation Technical Memorandum: Simulations of historically wet years, when the system was not supply constrained, may therefore be a poor indicator of the model's ability to accurately simulate future levels of development. Particular interest is therefore place on model results during the six-year drought of 1987-1992."

The Draft Reliability Report appears to offers up the Technical Memorandum Report entitled *CalSim-II Simulation of Historical SWP/CVP Operations* in order to support the legitimacy of the using CalSim-II to conduct the reliability analysis. If this is the goal then these two statements are problematic.

While the Draft Reliability Report gives no clear indication about what the adjustments referred to on page 11 entail, the fact that adjustments had to be made to generate the claimed correspondence shown in Figure 3-1 cannot stand without further explanation. The goal of the *CalSim-II Simulation of Historical SWP/CVP Operations* Technical Memorandum should have been to see if CalSim-II could be used to faithfully reproduce all aspects of system operations, not simply the SWP exports during the 1987-1992 drought. If the storage levels in SWP reservoirs were not faithfully reproduced and had to be adjusted in some unexplained way to generate the results in Figure 3-1, then the Technical Memorandum should not be used to build the creditability of the CalSim-II.

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In the same way, the comment in Appendix E that only the results for drought periods are critical for reliability analysis is not valid. The Technical Memorandum is being offered as support for the use of CalSim-II, not as a part of the reliability analysis itself. The claim that is being made is that the model faithfully replicated history and therefore has creditability in terms of simulating future conditions. The apparent recognition that the model did not do particularly well in normal and wet periods calls into question the validity of this claim.

In addition, even if CalSim II did accurately simulate deliveries in one past drought, that does not mean it can accurately simulate deliveries in a future drought, for constraints on the system are likely to be different. Water quality standards and endangered species protections have changed substantially since the 1987-02 drought, largely because the standards in place during that drought proved insufficiently protective. If the same drought conditions were to recur in the future, those heightened protections would likely prevent the SWP from exercising the same delivery capacity. CalSim II's predictions that those past diversions would be repeated therefore may prove the model's inadequacy rather than its credibility.

In keeping with the first comment, the inconclusive and somewhat opaque presentation of the *CalSim-II Simulation of Historical SWP/CVP Operations* Technical Memorandum results suggest that this report is about the reliability of SWP deliveries in the CalSim-II model and that the CalSim-II model is not a fully faithful representation of the how the system has been or presumably will be operated. Once again, it is fair to point out that if one wants to imagine future conditions then one must use some sort of model but the reader should not be left with the assumption that CalSim-II is a fully faithful representation of the system.

As an aside, Table 4 of the *CalSim-II Simulation of Historical SWP/CVP Operations* Technical Memorandum offers the most real, albeit limited, assessment of the reliability of the actual system if one is to assume that at some point in the future SWP contractors will consistently request their full Table A allotments. In 2001, contractors requested 4,124,126 ac-ft of SWP water and were allotted 1,607,570 ac-ft of supply. In 2003, contractors requested 4,126,929 ac-ft of SWP water and were allotted 3,714,233 ac-ft supply. These are two points on the exceedence curve of the real system reliability, certainly not enough to develop a robust reliability assessment. It is interesting to point out, however, that these delivery levels fall at roughly the 85% and 8% exceedence levels on the results for Study 4 that are meant to approximate current levels of development and demand (Figure 5.1). In terms of the hydrologic conditions 2001 and 2003 fall at approximately the 77% and 42% exceedence levels in terms of the Sacramento Valley water year index values for the period from 1922 to 1994 period simulated in CalSim-II. While far from a perfect metric for evaluating the performance of CalSim-II, this points out how the operations of the real system under roughly current conditions when nearly the full Table A amount was requested by the contractors compare with the simulated results.

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In terms of system reliability during dry periods, the most interesting conclusion to draw from this comparison is that actual operations in 2001, which benefited from a water supply associated with approximately the 75% exceedence level, provided a level of service of only 1,607,570 ac-ft while the CalSim-II simulations yielded a 75% exceedence level of supply of roughly 2,500,000 ac-ft (as read from Figure 5.1).

Page 16: "The Article 21 demand in the updated studies (4 and 5) is higher than the earlier studies for the December through March period."

It does not appear that DWR makes any attempt to explain why these higher levels were assumed. They are used in CalSim-II to prompt an export of water to SWP contractors when conditions warrant. While the Draft Reliability Report fairly comments on page 17 that "Incorporating supplies received under Article 21 into the assessment of water supply reliability is a local decision based on specific local circumstances, facts and level of water supply reliability required", including these numbers that are driven by a somewhat unjustified level of assumed Article 21 demand is not the clearest manner in which to present reliability analysis.

Page 25: "By referencing the curve for Study 5 in Figure 5-2, the following can be deduced":

- *In 75 percent of the years, the annuall delivery of the SWP is estimated to be at of above 2.7 maf per year (65 % of 4.13 maf).*

There is nothing special about the 75, 50 and 25% thresholds used in providing a narrative description of Figure 5.2 In fact it is equally valid to open and close the list of bullets with statements like:

- The maximum amount of water that can be delivered in response to full Table A demands with 100 percent reliability, in the CalSim-II model, is 187,000 ac-ft.
- Under the least supply constricted conditions the SWP will be able to deliver, in the CalSim-II model, the full Table A allotments.

Without even worrying about whether or not the assumptions used in the CalSim-II model are valid or not, these two statements are as valid as the three offered by DWR and they create a much different impression of SWP reliability.

Even if 100% reliability is not a valid standard, water utility plans for a system that will fail 25% of the time, as is the corollary of the 75% exceedence, are no more valid. Municipal utilities are often looking for, 90-95% reliability. According to these standards, Figure 5-2 suggests that the reliability of the system is between 1.4 maf and 0.8 maf. These numbers, which are no more or less valid than those reported by DWR, are perhaps more useful for water managers in assessing the reliability of a water supply.

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Page 26: "In the case of 1977, it is reasonable to assume that up to 500 taf of 1976 allocated Table A water could be carried over to 1977."
This sort of conditional post-processing of model output, which could have ripple effect across the rest of the simulation with potential changes in model results, is not valid and this whole section should be removed. To its credit DWR does not try and use any of this after the fact hand waving in the Table and Figures published in the Draft Reliability Report. Nonetheless, by including this narrative DWR is attempting to argue both that the model can be trusted and that the model cannot be trusted. This is not legitimate model interpretation.

Page 49: "The estimate could be viewed as too low because the Department of Water Resources (DWR) is planning to have facilities in place by 2025 that will increase the reliability of the SWP. The estimate could be viewed as too high because there is the potential for exports to be required to be reduced to protect endangered fish species."

It is inappropriate to speculate on what deliveries could be with new facilities when the information is to be used under the provisions of Senate Bill 221 to verify that water supplies are available for new developments.

Page 78: "Table E-1 Summary of the Expected Elasticity Index (EI) and Sensitivity Index (SI) for Selected Variables."

These very interesting results are included in the Draft Reliability Report and are then ignored completely interpreting the results of the reliability analysis. Let us for example attempt to recast the statement offered above:

- The maximum amount of water that can be delivered in response to full Table A demands with 100 percent reliability, according to the CalSim-II model, is 187,000 ac-ft.

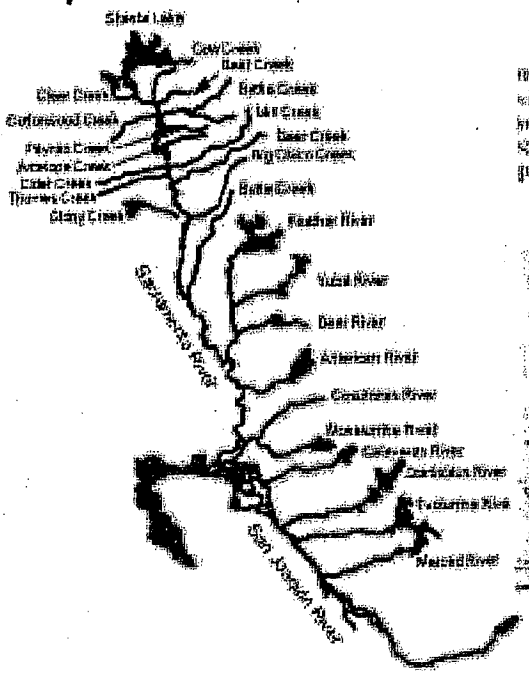
If the sensitivity analysis is valid, it is legitimate to make the following statements.

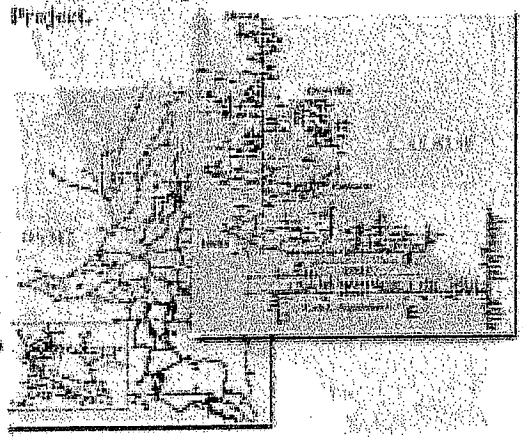
- If the assumed levels of Banks Pumping vary by ±10% relative to the base level assumed in the CalSim-II simulation, then the maximum amount of water that be delivered in response to full Table A demands with 100 percent reliability, in the CalSim-II model, will very between 184,195 and 189,805 ac-ft.
- If the assumed levels of Oroville inflows vary by ±10% relative to the base level assumed in the CalSim-II simulation, then the maximum amount of water that can be delivered in response to full Table A demands with 100 percent reliability, according to the CalSim-II model, will very between 182,138 and 191,862 ac-ft.

DWR should either make these sorts of statements or they should not attempt to use the results of the sensitivity analysis to assert the legitimacy of the use of CalSim-II for SWP reliability analysis.

1/8/2005 - touch "this approach" attachment #6 Norm

A Strategic Review of CALSIM II and its Use for Water Planning, Management, and Operations in Central California





Submitted to the

California Bay Delta Authority Science Program
Association of Bay Governments
Oakland, California

by

A. Close, W.M. Haneman, J.W. Labadie, D.P. Loucks (Chair), J.R. Lund, D.C. McKinney, and J.R. Stedinger

December 4, 2003

Executive Summary

1. Summary

The central all-encompassing question put to the panel is whether the CALFED program has adopted an appropriate approach to modeling the CVP-SWP-Central Valley system. Is the general CALSIM modeling approach appropriate for predicting the performance of the general facilities and for use in allocation planning, assessing water supply reliabilities and for carrying out operational studies? We believe the use of an optimization engine for simulating the hydrology and for making allocation decisions is an appropriate approach and is in fact the approach many serious efforts of this kind are using. It is a substantial improvement of the previous modeling approaches and provides a basis for consensus among federal and state interests. The modeling approach addresses many of the complexities of the CVP-SWP system and its water management decisions.

There exists a common tension between those who wish for greater detail and those who want less detail from the model. This argues for a more comprehensive, modular and flexible approach than is now available. In this report we suggest some ways this might be accomplished in the future. We also propose some management procedures that could be considered to improve model and model application quality control and documentation. The openness and availability of the model is admirable and very important given the numerous stakeholders who have interests in the management and allocation of water in the state. To increase the public's confidence in the many components and features of CALSIM II, we suggest that these components of CALSIM be subjected to careful technical peer review by appropriate experts and stakeholders.

2. Background

The California Department of Water Resources (DWR) and the U.S. Bureau of Reclamation (USBR) have developed a computer model called CALSIM II that simulates much of the water resources infrastructure in the Central Valley of California and the Delta region. This infrastructure is referred to as the CVP-SWP system. In particular CALSIM II provides quantitative hydrologic-based information to those responsible for planning, managing and operating the State Water Project (SWP) and the federal Central Valley Project (CVP). As the official model of those projects, CALSIM II is the default system model for any inter-regional or statewide analysis of water in the Central Valley of California.

CALSIM II has a central role in the analysis of many CVP-SWP and related issues, some of which require capabilities beyond those included in the model. California needs a large-scale relatively versatile inter-regional operations planning model and CALSIM II currently serves that purpose reasonably well. As the primary State and Federal-sponsored model available for water operations and planning, CALSIM II is critical to the study of many technical and policy issues related to water supply reliability, environmental management and performance, water demands, economics, hydrology and climate, and regulatory compliance.

CALSIM II is a particular application of the California Water Resources Simulation Model called CALSIM. It uses a mixed integer linear programming model solver to route water through a network over time. Currently it uses monthly time steps. Policies and priorities are implemented through the use of user-defined weights applied to the flows in the system (represented by arcs of the network). Simulation cycles at different temporal scales allow for successive implementation of constraints. The model can simulate the operation of relatively complex environmental water accounts and state and federal environmental regulations. In our judgment CALSIM II represents a very impressive modeling effort on the part of all those involved with its development and application.

The CALFED Science Program commissioned this external review panel (Appendix D) to 1) provide an independent analysis and evaluation of the strengths and weaknesses of CALSIM and CALSIM II, and 2) to offer suggestions on the appropriate uses of these modeling tools, on ways their use might complement or be complemented by other models, and on further development, quality assurance, and use in major water systems operations and planning in California.

The panel received background documents (Appendix B), including a survey by the University of California at Davis of stakeholder responses to questions about CALSIM II. We subsequently met for one and a half days in Sacramento for discussions and presentations (Appendix A) by CALFED, DWR and USBR staff. The discussions concluded with a summary presentation by the panel outlining our tentative conclusions.

The information we received and the shortness of our meetings with modeling staff precluded a thorough technical analysis of CALSIM II. We believe such a technical review should be carried out. Only then will users of CALSIM II have some assurance as to the appropriateness of its assumptions and to the quality (accuracy) of its results. By necessity our review is more strategic. It offers some suggestions for establishing a more complete technical peer review, for managing the CALSIM II applications and for ensuring greater quality control over the model and its input data, and for increasing the quality of the model, the precision of its results, and their documentation.

In this review we were asked to address the following questions:

1. Is CALSIM a reasonable modeling approach for current and proposed applications and problems?
2. Do other modeling approaches show similar or greater promise and flexibility for such problems? If so, how?
3. What are the major comparative strengths and weaknesses of the current CALSIM approach and alternative approaches?
4. What are major scientific, technical, and institutional limitations, uncertainties, and impediments for current and proposed applications of CALSIM?
5. What model, software, and data developments, special studies or tests would be beneficial to improve CALSIM for current and proposed uses?
6. How might CALSIM development and applications be managed and overseen to improve the quality assurance of model results for current and proposed applications?

7. What are your suggestions for long-term use, development, or replacement of the current suite of models and data available for the current and proposed uses of CALSIM?

The following sections of this summary present our responses to these questions. The main parts of this report and its appendices provide additional detail.

3. CALSIM Modeling Approach

CALSIM II is a simulation model developed as a joint venture between the California Department of Water Resources (DWR) and the U.S. Bureau of Reclamation (USBR) to (i) provide a significant modernization and upgrading of the DWRSIM and PROSIM models developed and used by these organizations, (ii) develop a comprehensive modeling system that simultaneously addresses the current and future needs of both the SWP and CVP systems; and (iii) develop a generalized modeling system that could be applied in any river basin system, in contrast with the previous models that were less generalized and more specifically designed for the existing SWP and CVP systems. In this respect, CALSIM II represents a state-of-the-art modeling system that is similar in general concept, while differing in specific details, to other data-driven river basin modeling systems such as ARSP, MODSIM, OASIS, REALM, RiverWare and WEAP.

CALSIM uses linear programming to solve sets of equations that simulate water movement through the CVP-SWP system in accordance with various objectives and constraints. This is a modeling approach which has been used successful in California (Johnson et al., 1991). In a complex system such as that being modeled, it is essential to have some mathematical representation of system flows that reflects all of the interconnections and constraints. Use of an optimization algorithm allows good decisions to be identified from among all possible and feasible decisions. To the extent this simulates what actually occurs, it is a good modeling approach. To the extent it optimizes when in reality no such optimization is implemented, it has the potential to produce inaccurate and overly optimistic outputs.

Most successful applications of optimization that attempt to simulate the behavior of a system have calibrated their objective functions (i.e., set the weights that prioritize flows over time and space) so that the model results correspond to what actually happens or would happen under a particular hydrologic and demand scenario. In these cases the model's decisions correspond to those the operators would make, as often prescribed by rules that have been worked out in a legal/political process. It does not appear that such a calibration of the objective function weights in CALSIM has yet been completed.

4. Other Modeling Approaches

There are two aspects of modeling, the model structure and algorithms used, and the model software. The use of linear optimization algorithms to solve simultaneous equations for simulating hydrology is a common way of avoiding a typically long list of procedural rules for simulating regional water systems. Such sets of procedures can be difficult to generate for

complex systems, and very different and new rule sets may be needed if structural or significant policy changes are to be investigated. In addition the performance of the system when simulated will be less than that which can be achieved in practice if a good set of rules is not provided. Optimization models are generally easier to reformulate when system changes are to be investigated. However unless the optimization is calibrated in such a way as to actually resemble what takes place in practice it can produce an optimistic description of system performance. This is particularly true if the optimization model is allowed to have perfect foresight of future events that in practice would not be available to system operators.

Large simulation models using optimization and procedural rules both need to have internal checks to ensure to the extent possible that errors in mass balances, for example, do not occur due to errors made when the model is being defined or created. Such internal checking is not apparent to us in our admittedly brief review of CALSIM II. Nor were calibration procedures well defined.

One obvious limitation of using linear optimization procedures is its inability to model accurately and efficiently some of the non-linear hydrologic and decision processes that occur in systems as complex as the CVP-SWP. One approach to addressing this issue of model accuracy, and possibly for decreasing the computational time as well, is to link linear optimization models to non-linear simulation models in a way that permits the simulation to represent the hydrology in any spatial and temporal detail desired. The optimization is used to determine what the decisions should be at every site where a water allocation, reservoir release, or other management decisions must be made. The time steps for simulation could be daily, or weekly or longer, depending on the needs of the user, but would likely be of shorter durations than the optimization time steps. After a predetermined number of simulation time steps, the optimization model would be run. The initial state of the optimization should be set at the beginning of each optimization time step. The optimization component should include multiple future time periods, with imperfect hydrologic and demand forecasts, but once solved only the current period's solutions are implemented – i.e., these decision variable values are sent to the simulation component. The decisions indicated for future periods are ignored. When appropriate, the initial state of the multi-period optimization model is updated and the model is again solved. And so on. Such a modeling approach may prove to be both more realistic, more accurate, and require less time, once developed. We believe such an approach might be worth considering for future development.

CALSIM II currently consists of a combination of software modules developed in several languages, including FORTRAN, Java and C. Several of the modules require proprietary software packages in order to run CALSIM II (Lahey FORTRAN and XA Solver). DWR and USBR staff have said that these components are being replaced by public domain software that can be obtained free of charge. We agree with this decision. Very good public domain software packages of optimization, visualization, file management, and data base support are currently available, and new ones will continually be produced. Periodic updates should be anticipated as part of the business of maintaining the modeling system.

Significant thought should be given to the sustainability of the CALSIM II software. How will future programmers be able to maintain this software? How will future software developments

be incorporated into the system? Will the solver currently being developed by LBNL be adequate in terms of accuracy and computation speed? Will other solvers need to be tested? Can the system accommodate these future developments without major modifications? What reasonable modifications could be made now in anticipate of future developments?

5. Comparative Strengths and Weaknesses

Many of the stakeholder perceived strengths and weaknesses of CALSIM and CALSIM II are very well identified in the survey report from the University of California at Davis (Ferreira, et al. 2003). Our background materials and briefings covered various strengths and weaknesses, but without first hand experience, all we can do here is to summarize those that we have heard expressed by others.

Here we provide a brief summary list.

5.1 Some Prominent Strengths

The strengths of CALSIM II are many. Most are expressed in comparison to previous DWRSIM and PROSIM models DWR and USBR were using. Some of these strengths include:

- Consensus model. CALSIM II is the official joint modeling environment of the State DWR and USBR. This includes a common schematic, hydrologic representation of the system, common set of facility capacities, and common representation of system operating policies. This helps all parties improve representations, rather than compete over representations.

- Common effort. The joint development of CALSIM II by USBR and DWR has provided more focused and effective use of resources and expertise than previous development of agency-specific models. CALSIM II development has also involved other agencies and consulting expertise more than pervious models of this system.

- Data-driven model. CALSIM II is a rather data-driven simulation model with an optimization engine. This modeling approach provides:
    a. greater flexibility than its predecessors and traditional water resources simulation approaches.
    b. a promising framework for improving transparency, data, and model documentation, compared to other approaches.

- Public domain. The model and data are substantially in the public domain, facilitating transparency and adaptability for California's decentralized water system.

- Steady improvements. Data improvements have been steadily pursued following the adoption of CALSIM II, although deficiencies remain.

- Improved Delta water quality representation. Although problems appear to remain, the model developers have made substantial gains in representing Delta water quality operating criteria and performance.

- Better groundwater representation. Efforts to better include groundwater and non-CVP-SWP project operations merit continuation and expansion.

- Benchmark Studies. The development of documented benchmark studies have resulted in significant model improvements and aided in the development of comparative model applications. Such exercises should be continued and improved.

- Long-term vision. The vision of a more transparent and publicly available model that can be employed by those outside the major agencies is excellent. This is a major change in direction, and achieving this vision will require adjustments over time. Often, these adjustments will be externally driven. Externally-driven improvements are a price of success and evidence of success for an open, public, modeling policy.

- Important CALSIM II features:
  a. CALSIM II is able to simulate the operation of the complete CVP-SWP system in all areas that contribute flow to the Delta in monthly time-steps.
  b. CALSIM II is being applied to examine a diverse range of options including flood control, water conservation and supply, power generation, recreation, water transfers, groundwater banking, recycling, desalination, conjunctive use, the purchase of options and streamflow and water quality protection.
  c. CALSIM II has successfully been applied by both DWR and USBR to examine both structural and non-structural changes to the CVP-SWP system as well as to ascertain the risks involved with different potential operating scenarios and to quantify the impacts of proposed actions.
  d. CALSIM II can dynamically model operation of environmental water accounts.
  e. Demands may vary according to various levels of development (e.g. 2001, 2020) and to hydrologic conditions.
  f. The regulatory environment under which the projects must operate can be simulated.
  g. CALSIM II can link to external modules as needed, e.g., to estimate the salinity at water quality stations within the Delta.

5.2 Some prominent weaknesses

As its strengths are many, so are its weaknesses. It seems worth saying, however, that no model can perfectly (meaning efficiently and effectively) serve all interests in a system as complex as the CVP-SWP. Tradeoffs need to be made. This can result in what some would call weaknesses. Such weaknesses are often accepted to gain strengths in another ways.

We heard that the CALSIM II model was too complex. We also heard that it did not handle particular components of the system with sufficient detail. And such is the dilemma of any

complex model, such as CALSIM II. The model is clearly too complex, and not complex enough. The root of this difficulty is that when such a model is constructed, it is not clear what level of detail is needed, so the model must be made sufficiently complex to ensure it is complex enough. And the complexity needed to address some issues will remain in the model when it is used to address other less complex issues, or the same issues at less complex locations. One approach to addressing this issue is to develop different linkable modules of CALSIM II having different complexities. In this way the level of detail can be varied to be consistent the application or study at hand, and level of sophistication and resources available to the user.

Other weaknesses model users would like addressed include:

- The model provides limited and inadequate coverage of non CVP or SWP water and of the California water system south of the Delta.
- The model assumes that facilities, land-use, water supply contracts and regulatory requirements are constant over this period, representing a fixed level of development rather than one that varies in response to hydrologic conditions or changes over time.
- Groundwater has only limited representation in CALSIM II.
- Groundwater resources are assumed infinite, i.e., there is no upper limit to groundwater pumping.
- The linear programming model considers only the current month, and hence CALSIM II operating rules are required to determine annual water allocations, to establish reservoir carryover storage targets, and to trigger transfers from north of Delta to south of Delta storage.
- Better quality control is needed both for the model and its current version and the input data. Procedures for model calibration and verification are also needed. Currently many users are not sure of the accuracy of the results. A sensitivity and uncertainty prediction capability and analysis is needed.
- Need improved ways of altering the model's geographic scope and resolution and its temporal resolution to better meet the needs of various analyses and studies.
- Need to improve the model's comparative as well as absolute (or predictive) capabilities.
- CALSIM II needs better capabilities for analyzing economic, water quality, and groundwater issues.
- Need improved documentation explaining how the model works, its assumptions, its limitations, and its applicability to various planning and management issues.
- DWR and USBR have not provided a centralized source of support for CALSIM II. More training for CALSIM II is needed. There is a need for more people who can run CALSIM II. There is a need for a well-publicized user group. A more extensive users' guide is needed.
- Improved capabilities are needed for real-time operations especially during droughts, gaming involving stakeholders during a simulation run, handling of evapotranspiration and agriculture demand changes over time, water transfers, Delta storage, carryover contract rights, refuge water demands and more up to date representation of Feather River, Stanislaus River, Upper American River, San Joaquin River and Yuba River operations.

- Need an improved graphical user interface to facilitate input of model data, setting of model constraints and weights, operating the model, and displaying and post analysis of model results.
- Need to be able to change the model time period durations for improved accuracy of model results.

6. Limitations, Uncertainties, and Impediments

6.1 Absolute Values or Comparative Results

Modelers sometimes make a distinction between the use of a model for *absolute* versus *comparative* analyses. In an absolute analysis one runs the model once to predict an outcome. In a comparative analysis, one runs the model twice, once as a baseline and the other with some specific change, in order to assess change in outcome due to the given change in model input configuration. The suggestion is that, while the model might not generate a highly reliable absolute prediction because of errors in model specification and/or estimation, nevertheless it might produce a reasonably reliable estimate of the relative change in outcome. The panel is somewhat skeptical of this notion because it relies on the assumption that the model errors which render an absolute forecast unreliable are sufficiently independent of, or orthogonal to, the change being modeled that they do not similarly affect the forecast of change in outcome; they mostly cancel out. This feature of the model is something that would need to be documented rather than merely assumed.

In our opinion CALSIM II has not yet been calibrated or validated for making absolute predictions values. Yet it is apparent that there has been a distinct need by model users for absolute predictions. In the absence of alternatives, users are adopting CALSIM II results as the best absolute prediction available and they are likely to continue to do so. We recommend that model developers recognize the requirement for CALSIM II to provide absolute predictions. To satisfy this new purpose, additional calibration of the model will be required to ensure that the output it produces is fit for this purpose. Regardless of how possible it is to match the model closely with observed behavior, statistics on the accuracy of the calibration run should be supplied to users to enable them to gauge the likely errors involved with using the model output.

6.2 Sensitivity and Uncertainty Analyses

Sensitivity analyses would be useful to identify which parameters and input data have major impacts on decisions and system performance criteria of concern. Uncertainty analyses would help users of the model understand better the risks of various decisions and the confidence they can have in various predictions.

6.3 Graphical User Interface

Having a graphical user interface would substantially aid those who use the model in managing both input and output data, and in controlling or managing model operations. This model will not likely become as available to and as well understood by the public, to the extent desired by the model developers, until an effective menu-driven GUI has been created that can help create and draw from a database of system parameters and characteristics, and simulation results.

6.4 Documentation and Training

When if ever is adequate documentation and training available? Rarely, but we believe there is a serious need to improve the documentation as well as the training available for all those interested in using CALSIM II.

7. Options for Improving CALSIM

7.1 CALSIM Model Software

We encourage the developers of CALSIM to convert their present software to that which is publicly available and to develop a useful graphic based user interface that can facilitate the input, editing, and display of all the data that are input to and output from CALSIM II. There are many options, some of which we have discussed with the model developers.

The CALSIM package should be made more modular and capable of linking to other more complex models of components of the CVP-SWP system. If the changes in code and modeling approach result in a quicker running model, it might be possible to link, when desired, modules that facilitate position analyses and other types of uncertainty analyses. A modular system would allow alternative representations of different components of the system. Thus different levels of spatial detail, or representations of the fundamental processes, would be allowed within the overall system representation and record of California hydrology. This will allow the use of more general and streamlined models for use of preliminary investigation and general planning, as well as a more detailed representation of the system for final analyses and more detailed studies. This would be very useful.

7.2 Sensitivity and uncertainty analyses

Both sensitivity analyses need to be performed, and procedures need to be developed to enable the estimation of measures of uncertainty associated with model output. Perhaps workshops focused on just these needs should be scheduled to better determine how best to meet these needs. There are numerous procedures available that could be applied. Appendix H contains some approaches for performing sensitivity and uncertainty analyses.

7.3 Model calibration

There is a need to develop the model so that it is able to provide absolute estimates of key model outputs rather than limiting the use of the model to comparative studies. One way to do this is to subject the model to a comprehensive calibration process where it is fine-tuned until it is able to reproduce the historical behavior of the system with sufficient accuracy to provide absolute results. The calibration of the model should aim to test all the key outputs of model including water quality in the San Joaquin River and in the Delta. It is necessary to test the monthly values of outputs for those outputs for which the monthly pattern is important.

7.4 Other extensions and improvements

- The opportunity of improving the collection of data on the use of water (preferably broken down by irrigation district and water source) should be investigated. The use of groundwater should be included in this investigation.
- It would be useful to expand the geographic extent of the model so that it includes all the components of the linked water supply system, including both the San Joaquin and Tulare Lake Basins of the Central Valley. The model should also account in some manner for imported supplies of water to users in southern California from the Colorado River.
- The linkage between surface water and groundwater would appear to be of critical importance and output that would enable the impact of surface water use on groundwater extractions would appear to be useful.
- Examination of the report *'CALSIM II Simulation of Historical SWP/CVP Operations'*, DWR (2003) indicates that the current formulation of CALSIM II:
  - Overestimates water deliveries to SWP and CVP contractors,
  - Determines carryover storage target values that differ from those the operators have determined in the past, and
  - Operates the San Luis Reservoir at lower levels and fills it later in the season than operators have in the past.

8. Managing CALSIM Development and Applications

The predicted impacts and other information derived from CALSIM II applied to the CVP and SWP can influence major investment decisions. It is thus self evident that those who use the model results need to have some confidence as to their precision. Is the science behind the information derived from CALSIM II been reviewed and judged correct? Is the model software free from errors? Are the assumptions made when performing the modeling the correct ones? Are the model results accurately and fully reported? In other words, just how much credence should decision makers place in the model output? Users of the model results should be assured that they are credible and unbiased. One way to help ensure this is to have the models, their associated software, and their applications under the control of some interagency organization that can oversee and provide quality control over model development, application and documentation. They can also plan and implement needed peer reviews.

One possible means of facilitating the peer review processes and for maintaining control on the particular versions of CALSIM II and accompanying models used for CVP-SWP planning and management decisions is to create an interagency modeling consortium (IMC) consisting of DWR, USBR, and other stakeholder organization (including university) personnel if they are interested and want to participate. This center would be responsible for maintaining a toolbox of 'acceptable' models for use by the agencies and contractors. The models placed in the toolbox should be peer reviewed with respect to their applicability and suitability for use in particular applications. Those that are not peer reviewed should be considered for peer review. New models proposed for use in California should be peer reviewed with respect to their suitability, and for their strengths and limitations, before being placed in the toolbox. The review should be of the theory underlying the model, the model's software, the documentation of the model as well as of its software, the model's functions and capabilities including those pertaining to model data input and output, the input data themselves, model calibration and verification, capabilities for sensitivity and uncertainty analyses, user control of all model operations including pre and post analyses (GUIs), spatial and temporal resolutions, and its limiting assumptions.

9. Future Use, Development, or Replacement of CALSIM

9.1 A coupled optimization simulation approach

Given a system as complex as the SWP/CVP system, it seems to us it might make sense to consider the development of a more detailed simulation 'engine' and couple it to an optimization or management 'engine'. The simulation component can more accurately model hydrologic processes. For example it can include the deterministic non-linear routing of flows and their quality constituents through the system on a smaller time step (e.g., daily) and hence much more realistically or accurately, than can linear optimization using longer time steps, even with all the known tricks for linearizing separable (single variable) non-linear functions and 'if-then-else' statements. The simulation engine itself may require a simultaneous equation solver, especially for the Delta. But the simulation engine needs to know what to do, i.e., what decisions to make. Periodic use of the optimization, say once a week or even less frequently if conditions are relatively constant, for determining the decisions to be simulated, e.g., the water allocation and reservoir release decisions, eliminates much of the maze of rules that otherwise would be required and which developers of CALSIM II are avoiding through the use of optimization. Each time the optimization or management 'engine' is run it is first updated with the current state of the system as determined from the more precise simulation 'engine'. The optimization component would include multiple time periods only to the extent that the current period's solution is not affected by the time horizon in the optimization. The other time period solutions are ignored. This coupled optimization-simulation approach has the potential to be both more accurate as well as quicker to execute. In our opinion it is worth considering for future development.

9.2 Models as hypotheses

CALSIM II is really about the future, not the past. Benchmarking studies can help establish the credibility of the model and provide estimates of its accuracy by comparing its performance to actual historical operations. A concern is how well the model reproduces historical operations, not whether it is valid or invalid on some absolute scale of perfection. But the real issue is how well CALSIM can predict what might happen in the future with sets of hydrological and meteorological conditions that have not yet been experienced, and may be significantly different from the past if climate variability and climate change are considered. In these cases the ability of the model to forecast what will happen depends both upon its ability to describe what would happen should a particular system operating policy, priorities and water demands be adopted. In this sense CALSIM II modeling studies should be thought of as the exploration of a hypothesis that particular policies and priorities have been adopted. Our ability to predict the future has generally been poor, but it is the obligation of agencies such as DWR and USBR to attempt to ensure that should water demands, water supplies, and water policies evolve as one would expect, society is prepared for the consequences. And that would seem to be what CALSIM II is about.

9.3 Future Model Development and Use

From the list of perceived weaknesses above, there are clearly many opportunities for further refinement of CALSIM II. Rather than attempt to meet all needs using only one model, namely CALSIM II, it seems preferable to improve its adaptability to various levels of detail through its ability to link to other models when additional detail in a particular region or for a particular feature is desired. For example, the monthly time step used by CALSIM II is sufficient for many studies. Yet some seasonal (multi-month) decision making is needed in CALSIM II to reflect decisions made by the SWP and CVP as to what Table A and other allocations to honor in full. On the other hand, it is clear that many water quality and ecosystem management decisions would profit from more detailed weekly or daily time steps. However, such shorted time-step models will need the guidance of a longer time-step model. As discussed earlier, models with shorter time scales can require increased spatial resolution, both of which lead to increased model complexity and a strong argument for model modularity.

Additional potential applications of CALSIM II include operational planning using gaming, or the involvement of potential decision makers during the simulation runs via a well developed graphical user interface, and to improve the capability of modeling water quality, energy production, conjunctive groundwater and surface water interactions and use, to mention a few.

There will always be a need to perform alternative 'what if' policy analyses where a relatively fast model that also provides some capability for uncertainty analyses is required. Perhaps CALSIM II will never be able to serve this need, and if so another more simplified modeling approach could be developed to fill that need. This simpler screening tool would be calibrated to produce results comparable to those of CALSIM II or observed data. Is this possible? We can not be certain but feel the idea should be seriously considered.

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Caveat

Just as all models are approximations of reality, so may all advice be an approximation of what it should be. We hope what we have written in this report is correct and useful, but encourage CALSIM model managers and California's water community to take our assessments and suggestions for what they are, arrived at based on our own experiences and some limited exposure to those who know much more about CALSIM and CALSIM II than we do.

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Appendix A: CALSIM II Science Review Schedule

Appendix B: Briefing Material for CALSIM II Peer Review

Appendix C: CALSIM II Review Process and Timeline

Appendix D: Peer Review Panel

Appendix E: Managing Model Development, Application, Documentation and Communication.

Appendix F: Analysis of the November 2003 CALSIM II Validation Report

Appendix G: Some Principles for Strategic Water Analysis

Appendix H: Model Sensitivity and Uncertainty Analysis

Appendix I: Model Calibration Examples

1. CALSIM Compared to Other Modeling Approaches

Management of complex systems such as coordination of the California State Water Project (SWP) and the Federal Central Valley Project (CVP) requires effective decision support tools for simulating and analyzing system components in a fully integrated manner. The classic definition of a decision support system (DSS) provided by Sprague and Carlson (1982) is *"an interactive computer-based support system that helps decision makers utilize data and models to solve unstructured problems."*

A DSS integrates the following interactive subsystems: (i) dialog generation and management subsystem (DGMS) for managing the interface between the user and the system; (ii) data base management subsystem (DBMS); and (iii) model base management subsystem (MBMS).

CALSIM II is a DSS developed as a joint venture between the California Department of Water Resources (DWR) and the U.S. Bureau of Reclamation (Bureau) to (i) provide a significant modernization and upgrading of the previous models DWRSIM and PROSIM employed by these organizations, (ii) develop a comprehensive modeling system that simultaneously addresses the current and future needs of both the SWP and CVP; and (iii) develop a generalized modeling system that could be applied in any river basin system, in contrast with the previous models that were less generalized and more specifically designed for the SWP and CVP. In this respect, CALSIM II represents a state-of-the-art modeling system that is similar in general concept, while differing in specific details, to other river basin modeling systems such as AQUATOOL (Valencia Polytechnic University, Spain), ARSP (Acres Reservoir Simulation Program) (Boss International, 2003), IRAS (Interactive River-Aquifer Simulation) (Loucks, et al. 1996), MIKE BASIN (Danish Hydrologic Institute, 2002), MODSIM (Labadie and Larson, 2000), OASIS (Randall, et al., 1997), RAISON (Young, et al. 2000), ResSim (U.S. Army Corps of Engineers, Hydrologic Engineering Center), Ribasim (River BAsin SIMulation Model) (Delft Hydraulics, Netherlands), REALM (REsource ALlocation Model) (James, 2003), RiverWare (Zagona, et al. 1998), WaterWare (Jamieson and Fedra, 1996), and WEAP (Water Evaluation and Planning System, 2003) (Hansen, 1994). All of these can be categorized as decision support systems since all three subsystems of a DSS are embodied within them.

A distinguishing feature of several of these modeling systems is the use of optimization on a period by period basis (not fully dynamic) to "simulate" the allocation of water under various prioritization schemes, such as water rights, without the presumption of perfect foreknowledge of future hydrology and other uncertain information. This is a valid approach since use of optimization overcomes the disadvantage of employing numerous, unwieldy prescriptive rules governing water allocation. Systems employing optimization in this manner include: ARSP, MODSIM, OASIS, REALM, RiverWare, and WEAP and are therefore more akin to CALSIM II. ARSP, MODSIM, REALM and Ribasim are further distinguished by use of specialized minimum cost network flow optimization algorithms, although of these only MODSIM includes iterative structures using an imbedded scripting language for including non-network "side constraints" in the optimization. The other modeling systems are essentially limited to a

pure network structure that does not allow inclusion of all the complex, non-network type constraints necessary to model the complex CVP-SWP system.

It may be useful to compare this use of optimization with some other uses that have appeared in the modeling literature. One use of optimization is purely for computational convenience; in this case optimization is employed as a numerical method for obtaining the solution of a series of simultaneous (often linear) equations. This approach, which was used in the first generation of computational economic models about forty years ago, exploited the fact that some existing computational algorithms for solving optimization problems were faster than those for solving large systems of simultaneous equations. A second use of optimization applies when the solution of the system of equations characterizing a water balance has multiple possible solutions; this is essentially the case described above, where optimization is being used primarily to identify a unique solution for a system of equations. Both of these uses of optimization are primarily descriptive rather than prescriptive (also referred to as positive vs. normative) in intent: the goal is to model how a system, characterized by a set of equations, operates. To the extent that the real–world managers of the system do optimize some objective function, the aim is to mimic their behavior by setting up and solving a similar optimization. But, the goal is to model what they actually do, not to advise them what they ought to do. The third use of optimization adopts an explicitly prescriptive goal and sets out to ascertain what managers ought to do if they wished to optimize some objective function (e.g. maximize economic efficiency). While this is certainly a legitimate analytical exercise, it should be kept conceptually distinct from the use of optimization in a purely descriptive context.

1.1 Advantages of Optimization-Driven Simulation

For large, complex, integrated systems, simulation models that optimize operation and allocation of water within each time-step by operational priorities have become the major simulation approach. Models of similar approach include ACRES (Acres Engineering), AQUATOOL (Spain), MODSIM (Colorado State U.), OASIS (Hydrologics, Inc.), WASP (Australia), and WEAP (Tellus Institute). Priority-based simulation models with optimization engines have become widespread in part because:

- The models are simpler to develop, comprehend, and modify.
- Their software is easier to upgrade, since the data set describing the system and its operating policies is substantially separate from the software code.
- Data are easier to update and modify, since changes require little or no software changes.
- Priority-based operations are a common basis for water rights and operating policies.
- Priority-based operations are relatively easy to explain.

The major exception to this technological trend in simulation modeling is to use more traditional procedural operating rules in simulation models with a graphical user interface for primarily flood control operations (HEC-RESSIM) or for exploratory study of large systems or detailed management of relatively small systems (Stella-type models).

Similar to several of these systems, CALSIM II allows specification of objectives and constraints in strategic planning and operations without the need for reprogramming of

complex models. The CALSIM II authors developed the English-like WRESL (Water Resources Engineering Simulation Language) as an intuitive means of defining the objective function and constraints for a mixed-integer linear programming model, similar to the OCL (Operational Control Language) used in OASIS and the Policy Editor employed in RiverWare. In MODSIM, the optimization model is formulated directly through the graphical user interface with no need for a modeling language, but with supplemental features of the optimization defined through the PERL scripting language. WRESL allows planners and operators to specify targets, objectives, guidelines, constraints, and their associated priorities, in ways familiar to them. WRESL provides simple text file output that is converted to FORTRAN 90 code by a parser-interpreter program, whereas PERL is fully embedded in the network optimization code. Both modeling systems are data centered, meaning that model operation is controlled solely by user specification of input data rather than hidden rules or hard-wired data structures.

CALSIM II, OASIS, RiverWare and MODSIM are similar in that all use a high level language with syntax and logical operators; are written to simple text files which are subsequently parsed and interpreted; use rule-based or IF-THEN-ELSE conditional structures; are designed to be easy for planners and operators to use without the need for reprogramming; allow adaptive and conditional rules which are dependent on current system state variable information; include constructs for assigning targets, guidelines and constraints, along with their associated priorities; and include a goal seeking capability. CALSIM employs a mixed integer linear programming solver for repeated period by period solution that is less efficient computationally than the network solver employed in MODSIM, ARSP, REALM and Ribasim.

Unfortunately, unlike these aforementioned modeling systems, CALSIM lacks a comprehensive graphical user interface for constructing and editing the river basin system topology. CALSIM II would be greatly enhanced if, similar to RiverWare, IRAS, and MODSIM, objects representing features of the basin such as reservoirs, canals, and river reaches, could be created on the palette of a graphical user interface by simply clicking and dragging various icons for the objects to the display. The objects are instances of various classes that share certain common characteristics, and each object contains its own physical process methods and associated data. We believe that complaints concerning the complexity of using CALSIM II would be greatly reduced with development of such an object-oriented graphical user interface.

2. Comparative Strengths and Weaknesses

2.1 Some Prominent Strengths

CALSIM II has important strengths as a general inter-regional operations planning model, particularly compared with available alternatives and its predecessors. The primary strengths include:

- Coordination of Federal and State Interests A unique aspect of CALSIM II is the high degree of cooperation between Federal (i.e., U.S. Bureau of Reclamation) and State (i.e.,

California Department of Water Resources) interests in its development. This kind of cooperation is rare, and in fact this may be the only such example of such coordination for a system of this scale and complexity. Although it is clear that DWR staff have taken the greatest degree of responsibility in the planning, development, coding, testing and application of CALSIM II, it is also clear that USBR staff have also played an important role. CALSIM II can provide a showcase for other states as to what can be accomplished with Federal and State cooperation for river basin management.

- Consensus model. CALSIM II is the official joint modeling environment of the State and USBR. This includes a common schematic, hydrologic representation of the system, common set of facility capacities, and common representation of system operating policies. This saves a lot of unproductive bickering and helps all parties improve representations, rather than compete over representations.

- Common effort. The joint development of CALSIM II by USBR and DWR has provided more focused and effective use of resources and expertise than previous development of agency-specific models. CALSIM II development has also involved other agencies and consulting expertise more than pervious models of this system.

- Data-driven model. CALSIM II is a rather data-driven simulation model with an optimization engine. This modeling approach provides:

    a. much greater flexibility than its predecessors and traditional water resources simulation approaches.
    b. a promising framework for improving transparency, data, and model documentation, compared to other approaches.

- Public domain. The model and data are substantially in the public domain, facilitating transparency and adaptability for California's decentralized water system. Ongoing software development efforts will improve CALSIM in this regard.

- Steady improvements. Data improvements have been steadily pursued following the adoption of CALSIM II, although deficiencies remain widespread.

- Improved Delta water quality representation. Although problems appear to remain, the model developers have made substantial gains in representing Delta water quality operating criteria and performance.

- Better groundwater representation. Efforts to better include groundwater and non-CVP-SWP project operations are good efforts in the right direction, and merit continuation and expansion.

- Benchmark Studies. The development of documented benchmark studies seems to have resulted in significant model improvements and aided in the development of comparative model applications. Such exercises should be continued and improved.

- Long-term vision. The vision of a more transparent and publicly available model that can be employed by those outside the major agencies is excellent. This is a major change in direction, and achieving this vision will require adjustments over time. Often, these adjustments will be externally driven. Externally-driven improvements are a price of success and evidence of success for modeling policy that is open and public.

Few, if any, modeling organizations in the country have consistently done as good a job on model development and application for such a large, complex, and controversial system as the modeling group which developed CALSIM II. They are to be commended for their work to take California water modeling beyond past "closed shop" practices in favor of the development and dissemination of modeling capabilities that are more relevant to California's current water management problems. Most areas and suggestions for improvement noted below are meant to aid the model developers in moving further and faster in the direction they are already heading.

2.2 Some Prominent Weaknesses

The strengths and weaknesses of CALSIM II are not only technical (software, data, and methods), but also are institutional regarding how this model has been developed and employed. The administrative setting and objectives of model development and application are important, and difficult to manage. Alas, the management/policy problems of a system change frequently, while data and modeling capability change more slowly, and effective administrative structures change very slowly, if at all.

- Inadequate data development and management are principal shortcomings of CALSIM II. There has not been a sufficiently systematic, transparent, and accessible approach to the development and use of hydrologic, water demand, capacity, and operational data for CALSIM II. This problem extends beyond inadequate documentation and has led to controversy, confusion, and inefficiency in application of CALSIM II.
    a. Inadequate data management steepens the unavoidably difficult learning curve inherent for a complex system. Data have mostly been considered a "back room" activity of a few experienced experts. Retirement, promotion, or departure of these experts has left many gaps in knowledge and created difficulties for re-developing data for newer policy and planning problems.
    b. The administration of data development is fragmented, disintegrated, and lacks a coherent technical or administrative framework. Data required by CALSIM II are developed by several administrative units, without systematic technical vision or quality control for modeling purposes. Within DWR, different groups develop hydrologic and water demand data under different Deputy Directors, without effective coordination. This division must be overcome for a coherent data and analytical framework to be developed and implemented.
    c. In many cases it appears that water use and other hydrologic data inputs to CALSIM II are based on data collection and analyses that took place during the 1960s when DWRSIM and PROSIM were being constructed. It is important to ensure that data used for CALSIM II are up-to-date and consistent with the best current information

- The expertise and insights of many in local agencies, system operators, and consulting firms have not been prominent in the development of CALSIM II. For such a system with many hundreds of local experts, this is somewhat unavoidable, especially early in model development. Periodic re-examinations of how each area in CALSIM II is represented, in consultation with local agency and consulting experts, might overcome these technical shortcomings, and create and maintain a broader technical, user, and credibility base for CALSIM II. Active involvement of local agencies in CALSIM II development and applications would be much easier with better data management, and would be rewarded with a broader base of CALSIM II expertise and enhanced model credibility.

- Compared to the current CALSIM II, any central operations planning model for California water management should be:
    a. Expanded in geographic scope to include major non-CVP-SWP areas, especially the Tulare Basin, the Colorado River, and southern California. Operations and demands in these regions seem increasingly important for CVP and SWP operations, and are important for the integrated operations of California's major local and regional water management agencies.
    b. Expanded in management scope to include local management options such as water conservation, reuse, water transfers, groundwater and conjunctive use management, etc. These additional water management options are important for local, regional, and statewide water policy, planning, and management efforts and can have significant effects on CVP and SWP water demands.
    c. Made regionally modular, so smaller regional models can be run independently and tested locally, with boundary conditions consistent with the larger model.
    d. Made modular in terms of hydrologic, water management, and water demand processes, allowing better development, comparison, and updating of hydrologic and water demand process models. Agricultural, urban, environmental, and other water demands should be represented more directly, and explicitly. Groundwater should be represented and operated more explicitly. Land use based local hydrology and water demand approaches might be implemented in such standardized modules.
    e. Subject to a systematic model and data testing regime and continuous quality improvement program. As the problems of California water change, different and greater demands will be placed on analytical capability, requiring an essentially continuous testing, re-testing, and improvement of data and models. This might parallel a continuous review of local representations and data involving local agency and consulting experts.
    f. Financed on a broader base, by more than the CVP and SWP projects. Increasing use of CALSIM II is being made by local, regional, State, and Federal agencies interested in developing bilateral or multi-lateral water transfers or projects, which incidentally involve the CVP and SWP. To develop inter-regional modeling capability needed to integrate these activities at local, regional, and inter-regional scales, more sustained funding and involvement from local and regional agencies is needed. In effect, local and regional agencies have been "free riders" on CALSIM

II's analytical capabilities, and it is not necessarily a good bargain for them. Everyone should benefit from broader technical and financial participation.

g. Capable of analyzing a wide range of scenarios. More capability is needed to examine various long-term scenarios with respect to hydrologic, water demand, and operational uncertainties in the future. There also needs to be a better capacity to accommodate other approaches to representing hydrologic uncertainty and variability besides simply simulating 70-plus years of record.

- Input data and its development. Important aspects of CALSIM II rest upon the representations of other models of Delta hydrodynamics and water quality, water demands, and groundwater. The credibility of CALSIM II also rests on testing these models that send important data/representations to CALSIM II, and documenting them adequately. These models include:

  a. CU Model and SIMETAW: The consumptive use model and the newer SIMETAW model, used to develop hydrologic inputs and estimate return flows, also require testing and more explicit documentation. The underlying data for these models also need more systematic, standardized, and transparent treatment.

  b. DSM2: Representation of the Sacramento-San Joaquin Delta will always be important and prone to controversy, given the prominent importance of Delta flows and water quality for the operation and planning of California's water system. The difficulties of representing the Delta in operations and planning models are compounded by the tidal nature of the Delta, which usually implies a need for shorter time-steps. Representation of Delta water quality constraints currently falls heavily on an ANN method within CALSIM II. This ANN is calibrated (trained) based on a hydrodynamics model, DSM2. Thus, controversies regarding Delta representation in CALSIM II are likely to lead to questions of the adequacy of DSM2. The transparency and testing procedures valuable for establishing the credibility and limitations of a Central Valley operations model would also seem to apply to DSM2, or any other Delta hydrodynamics-water quality model. Tests of methods used to represent small-time step phenomena with larger time-steps (e.g., "partial month standards") should be tested in a forum that would give the approach credibility and where its limits could be developed, discussed, and documented.

  c. CVPM/CALAG/LCPSIM/IWR-MAIN: Representations of water demands in CALSIM II rely heavily on other models, particularly CVPM and eventually CALAG for agricultural water demands and LCPSIM and eventually IWR-MAIN for urban water demands. Thus, these models also will attract attention, and will probably require the same types of testing, transparency, and documentation suggested for DSM2 and CALSIM II. Many water contractors of the CVP and SWP also have internal water sources (groundwater, water conservation, and water reuse) and side contracts with other agencies to supply water that can increase or decrease (at different times) their water demands from the CVP and SWP contracts and from the demands estimated from CALAG and IWR-MAIN types of models.

  d. IGSM /CVGSM: Water users in California rely on groundwater as a water source and as the major source of over-year drought storage. Groundwater is also being increasingly used and looked-towards as a source of storage as part of conjunctive use schemes, and water transfer and market schemes. Thus, representation of

groundwater in the system is important, and probably should be expanded considerably. The representation of groundwater quantities, storage, and recharge and pumping capability will also attract attention from interested and critical parties. Thus, the IGSM/CVGSM modeling efforts of DWR and USBR should include the same types of transparency, documentation, and testing suggested for CALSIM II.

e. Agricultural demands: Agricultural demands in the model are estimated by an external modeling system (CU model). Staff noted that the estimation methods being used are include out of date information on agricultural cropping patterns and irrigation technology, both of which result in inaccurate estimates of agricultural water demands. This estimation process needs to be revised and updated to include current information on an ongoing basis. The methodology needs to be improved to include economic factors in the estimation of cropping decisions and water demands. In many case, the preferred spatial scale for the economic modeling of agricultural water demand is going to be the individual irrigation district rather than very broad areas containing multiple quite heterogeneous districts.

- CALSIM II is currently awkward to apply for broader State and CVP-SWP policy questions. Practically, the time needed to complete analyses is too long and CALSIM II does not explicitly represent many of the management options which policy makers are interested in investigating, evaluating, and orchestrating.

- More CALSIM II modelers are needed. Many water managers and policy makers across California look to CALSIM II for many purposes, and there is near-universal consensus that the application of CALSIM II is currently limited by a dearth of knowledgeable modelers. Current training by DWR and USBR on CALSIM software is useful, but clearly insufficient. To be a functioning and credible CALSIM II modeler one must understand both CALSIM software and the operational complexities of the system (which probably no one can know in its entirety). Improved model and data documentation is also essential here.

- Stakeholders and policy makers are poorly guided in how to interpret CALSIM II results. Not only must CALSIM II become more responsive to current planning and policy concerns and management options, but current policy makers must receive some education in the benefits and limits of such modeling for their purposes. This is a very difficult problem that will often involve the role assigned to modeling and model results within larger politically-driven policy making processes.

- Non-interpretation of model results is not helpful. Several recent DWR reports based on CALSIM II results have been considerable improvements over past practices in terms of presenting model results, discussion of the model, and examination of model performance in a historical context. However, often the studies have not contained the kind of written discussion and interpretation of results that would demonstrate that the authors have thought about the results and drawn conclusions in a realistic and self-critical manner. This detracts from the perceived credibility of the work and makes the study less informative for readers (most of who surely do not have the modeling background of the authors).

- Some needs exist to improve CALSIM software. These are well-known to the model developers and include:
  a. Elimination of the need for the FORTRAN compiler,
  b. A public-domain mixed integer-linear programming (MIP) solver,
  c. A graphical user interface, including ties to databases and GIS display if possible,
  d. Post-processing tools for users to help new users and broader application and scrutiny of CALSIM II results,
  d. Version control software and system (also a problem for model administration),
  e. Better data and database management software and protocols (this has great data management and administration implications),
  f. An ability to more systematically set objective function weights,
  g. More automated input and output data checking is needed to improve productivity in model application and quality control of modeling output. This would also facilitate use of CALSIM II by a broader range of modelers,
  h. Ability to access and employ sensitivity analysis information coming from the MIP solver to identify possible multiple optima and identify binding constraints and slacks,
  i. A debug version of the code where water can be added or subtracted at any location and time (at a great penalty) to quickly identify locations and times of model infeasibilities. (Prof. J. Lund has had great success with this approach to correcting infeasibilities in the CALVIN model of California for a network flow algorithm.),
  j. Time-step issues should be explored and evaluated comparatively. There are major drawbacks to shortening time-steps system-wide (run-time, data development, interpretability of results, etc.), but short time-step components within the model or other approaches might adequately represent short-period aspects of the system for many purposes.

There will be some who argue that CALSIM II is and should remain a model of only the CVP and SWP system. While this would be simpler administratively and financially, it seems technically and politically untenable. California's water system is being asked to operate in an increasingly integrated manner across local and regional scales, with multiple local water demands, supplies, and aquifers being coordinated with the operations of major aqueduct and storage infrastructure. Any model of the CVP and SWP systems must be responsive to this operational integration, either implicitly through better parameterization of local supplies and demands, or explicitly by widening the geographic and functional scope of the model.

3. Limitations, Uncertainties, and Impediments

3.1 Removal of Unnecessary Ties to DWRSIM and PROSIM

Much of the spatial detail employed in CALSIM II is a carryover from the previous DWRSIM model. This is particularly evident in the coarse delineation of watersheds and sub-areas, which may no longer be relevant for future applications of CALSIM II. It is recommended that all unnecessary ties to the previous DWRSIM and PROSIM models be removed in further development of CALSIM II.

3.2 Relative vs. Absolute Predictions

As noted in the Executive Summary, we are skeptical of the usefulness of the distinction between comparative and absolute predictions. To declare that CALSIM II is intended for comparative predictions and should not be used for absolute predictions is not a helpful or desirable strategy. Rather than embracing this limited view of what CALSIM II can be expected to accomplish, we recommend that model developers recognize the requirement for CALSIM II to provide absolute values. To satisfy this purpose, additional calibration of the model will be required to ensure that it provides a reasonably reliable depiction of how the California water system operates. In addition, data on model accuracy and the outcome of the calibration runs should be made available so that users can gauge the likely errors involved in using the model for their own particular purposes. Some methods for doing this and performing sensitivity and uncertainty analyses are contained in Appendix H.

Model uses should realize that model calibration and validation exercises can illustrate only how well the model can reproduce historical decisions and system behavior. Our ability to predict future policy decisions and the emergency responses to water shortages is clearly limited, thus decreasing the absolute precision of any model's predicted values of various system performance measures. Thus it is useful to distinguish between the ability of the model to reproduce correctly the physical operations of the water systems in California (which should be good), its ability to reproduce and anticipate decisions by the agricultural sector that determine the quantities of water the consume, and its ability to mimic historical and current water operation decisions by the CVP, SWP and other water management agencies.

In general, it appears that the developers of CALSIM II do not have a clear idea of how to define the scope of CALSIM II use and many of the applications are evolving in a reactionary manner. Model developers should identify clearly the desired uses for CALSIM II and then determine acceptable approaches for satisfying those desires. Developers should seek to improve data accuracy and overcome unrealistic assumptions to improve confidence in model results.

3.3 Hydropower

CALSIM II is currently greatly lacking in hydropower computations, which is an important of the federal CVP system. This should include risk-based power capacity evaluation, and possible incorporate the ISM (indexed sequential hydrologic modeling) method that the Bureau has used for many years in hydropower capacity analysis. Also, hydropower should not simply be an after-the-fact calculation, but explicitly included in the system objectives.

3.4 Daily operations

A great challenge awaits the developers as they attempt to adapt CALSIM II to daily operations. These challenges are primarily related to the impacts of routing on distribution of flows and scheduling of reservoir releases. Under the current period-by-period optimization structure over daily time increments, without appropriate consideration of routing there is the

danger that the model will allow diversion of upstream flows to lower priority users, resulting in injury to higher priority downstream users in the following days where travel times exceed 1 day. The proper inclusion of routing in the daily operations requires some kind of look-ahead capability in CALSIM II, which is currently lacking. In addition, scheduling of reservoir releases on a daily basis creates difficult timing issues in order to minimize unnecessary downstream spills or shortages caused by routing and attenuation of upstream reservoir releases. Another complexity in moving into daily operations is that reservoir discharges now become head-dependent, whereas this can usually be ignored on a monthly time scale. This means that the maximum reservoir release in any day will be dependent on the head, and should be based on the average head over the day, which introduces the potential for time consuming iterative processes to deal with nonlinear relationships in discharge-head curves for any reservoir.

3.5 Groundwater model

Groundwater has only limited representation in CALSIM II. This resource is modeled as a series of inter-connected lumped-parameter basins. Groundwater pumping, recharge from irrigation, stream-aquifer interaction and inter-basin flow are calculated dynamically by the model.

The purpose of the multi-cell groundwater model is to better represent groundwater levels in the vicinity of the streams to better estimate stream gains and losses to aquifers.

In the Sacramento Valley floor, groundwater is explicitly modeled in CALSIM II using a multiple-cell approach based on DSA boundaries. For the Sacramento Valley, there are a total of 14 groundwater cells.

Currently no multi-cell model has been developed for the San Joaquin Valley. Instead stream-aquifer interaction is estimated from historical stream gage data. These flows are fixed and are not dynamically varied according to stream flows or groundwater elevation.

The approach to modeling groundwater in CALSIM II, a lumped-parameter "tank" model seems to be a reasonable approach. However, few details of this implementation were provided to the review panel, that it is not possible to assess its accuracy or reliability. Details of the calibration and verification activities performed to date should be carried out and reported for the groundwater tank model. The effect of using large size tanks should be assessed and the level of uncertainty in computed results reported. In addition, the effect of these uncertainties on CALSIM II calculations should also be assessed. The San Joaquin valley aquifers are not well represented in the tank model, but it is in the CVGSWM. The San Joaquin valley groundwater should also be modeled in CALSIM II.

Groundwater availability from aquifers is poorly represented in the model. This results from the fact that aquifers in the northern part of the state (Sacramento Valley) have not been investigated regarding storage and recharge characteristics. Thus, in the model, upper bounds on potential pumping from aquifers are undefined. This does not represent reality, since, if CALSIM II is used for statewide planning, it would allow pumping of vast quantities of water for export to southern parts of the state, something which agency staff claim is unrealistic.

Realistic upper bounds to pumping from any of the aquifers represented in the model need to be developed and implemented.

In addition, historical groundwater pumping is used to estimate local groundwater sources in the model. However, the information on the historical pumping is very limited, causing these pumping rates to be very uncertain. Better pumping information is needed and an analysis of the effect of this uncertainty on model results needs to be conducted.

In general, the level of representation of groundwater in CALSIM II is not reasonable from the point of view of the reviewers. This is due to several factors, perhaps the most important being the lack of information presented to the reviewers for their assessment. Another factor is the lack of data collected and analyzed by the State of California to properly account for groundwater resources in the Central Valley. These data are critical to an understanding of the availability of water in the state and the operation of the major water systems that supply water to agriculture and small municipalities in the Central Valley. Assumptions of unlimited groundwater resources in the Sacramento Valley are unfounded and unbelievable. Efforts should be taken to make reasonable estimates of these resources.

There are other approaches that provide reasonably accurate estimates of river-aquifer interactions and groundwater basin response, while not sacrificing computer time. The response function approach is a good example, whereby the CVGSM model is used to develop kernel functions describing this response. A similar approach is described in Fredericks, et al. (1998). These kernels may require readjustment as head conditions change in the basin, but they provide a more accurate prediction tool and are easily incorporated in the MIP model since they apply a linear superposition assumption and retain the linearity of the constraints in the model. A dynamically linked CALSIM-CVGSM configuration is not necessary for reasonably accurate solutions. If computer run time for CALSIM II is considered excessive now, it could only considerably worsen if this type of linkage is incorporated.

Soil moisture is not dealt with in a realistic manner and needs to be improved in applications where the model output might be sensitive to these assumptions.

3.6 Dynamic Variation of Priority Weights

A severe restriction in CALSIM II is the inability to dynamically vary the weights used to prioritize flow allocation in the system. It should not only be possible to dynamically vary these weights, but this variation should be conditional on the current system state, however that state (or states) is defined. In addition to dynamic variation of weights, more explanation is needed of the reservoir operating rules and how these rules are incorporated into CALSIM II. The description of operating rules used in the system is not very clear. For example, what kinds of hedging or shortage rules are used to mitigate the effects of drought?

3.7 Expanding Scope of CALSIM II

CALSIM II is a considerable advance on earlier models in that it fully incorporates both the State Water Project run by the Department of Water Resources and the Central Valley Project

operated by the Bureau of Reclamation. However to be able to examine the full range of Californian water issues, it would be desirable that all components of the linked system should be incorporated in the model including the Friant system, the larger Tulare Basin, and southern California and its links to the Colorado River. Also because of the very important linkage between surface water and groundwater use, improvements should be made in this area particularly with regard to how that linkage affects demand for surface water and how access to groundwater reduces the economic impact of surface water restrictions.

When expanding the geographical scope of the model to include non CVP-SWP areas, as well as Southern California, a hierarchical, decomposition approach would allow development of separate models for these areas that can then be linked together through iterative processes. Otherwise, the CALSIM II model can become extremely unwieldy. Again, integration can still be achieved through appropriate iterative interaction between the regional models. In the same vein, it is also unnecessary to explicitly integrate water quality and detailed water demand/consumptive use models into the model structure. Iterative schemes involving successive estimation of water quality and other parameters can produce comparable accuracy at reduced computer run times, while reducing the complexity of the model.

The replacement of DSM2 with a neural network is consistent with reinforcement or machine learning methods which are increasingly being used to replace complex, computationally time consuming models employed in decision support systems. The complex models are only used to provide the data sets used for training the neural network. Current research at Colorado State University and elsewhere is using neural networks for groundwater surface water interaction and return flow computation to replace computationally expensive groundwater models.

3.8 Key Model Outputs

In the past, the primary purpose behind the development of CALSIM II and its predecessors has been the examination of the reliability of water supplied to the State Water and the Central Valley Projects. However it is clear that there is now a demand for a model that will provide a wider range of outputs including:

- Water supply reliability for all water users
- Demand for water by existing users
- Outflows to Delta
- Use of groundwater and the rate of depletion of aquifers
- Water quality in the Delta and in the San Joaquin River
- Indicators of ecological health in particular with regard to key fish species
- The value of hydroelectric generation.

Although the modules in the CALSIM II package currently address many of these areas, the recognition that all these outputs are important may necessitate some further model development and a greater degree of testing and calibration of these parameters.

3.9 Modeling Allocation, Accounting and Operating Rules

CALSIM II uses a system of weights and constraints to define the water allocation process and the operating rules for storage reservoirs. Unfortunately these do not accurately reflect how operators of the state and federal water projects behave in managing their complex systems. Ideally, CALSIM should both reflect how the operators behave and be accepted by them as a useful tool when considering their management alternatives. The failure to achieve this limits the usefulness of CALSIM to investigate the specific operating or accounting rules that are of interest to those operators. For example, CALSIM II was not used to test changes to the accounting and allocation rules that have recently been proposed by the Department of Water Resources and the US Bureau of Reclamation because the rules that were changed do not exist in CALSIM II.

4. Options for Improving CALSIM

4.1 Optimization Model and Run Times

Many of the complaints regarding using of CALSIM II relate to long run times, which is not conducive to sensitivity or uncertainty analyses. Since CALSIM II employs a mixed integer linear programming (MIP) solver, the usual sensitivity information available in linear programming solvers, such as dual variables and right-hand-side ranging, are not available. The problem is that small changes in right-hand-side constants or objective coefficients (i.e., weights on water allocation priorities) can produce large abrupt changes in model solutions. In this case, dual variables do not provide useful information for MIP problems. Sensitivity analysis can only be conducted through trial and error processes involving incremental adjustment of important weights, coefficients, and uncertain data inputs with subsequent repetitive execution of the model. In light of this, it is crucial that the MIP solver employed in CALSIM II is upgraded. Significant advances have been made in MIP solvers, as described by Bixby, et al. (2000), which are not reflected in the current XA solver utilized in CALSIM II. There have been many recent improvements to the branch and bound method which should be incorporated, and the LP solver itself can be improved with better sparse matrix analysis. As planned by the CALSIM II developers, removal of the need for use of the FORTRAN 90 compiler will also improve run times when changes in optimization model structure are required.

4.2 Confidence in the model

The usefulness of a computer model in water resource management is only as good as the confidence that the stakeholders have in the accuracy and reliability of the model and the trust that they have in the modelers. There are several factors that affect that confidence and a number of ways that confidence can be improved.

- **Documentation**

Producing documentation of models requires considerable resources to do properly and ongoing resources to maintain especially when model development is continuing. Typically documentation of any water resource model is poorly done. However, where there are external model users, as is the case with CALSIM II, it is important. The survey conducted by Ferreira et al (2003) indicated that many users of the model thought that documentation of CALSIM II was poor.

- **Seminars**

In the Murray-Darling Basin, seminars with key users and interest groups in which the operation of the model is described and discussed have proved to be useful in increasing confidence in models. The practicality of this approach will depend on the number and location of the prospective participants and the resources available to support the process.

- **Data**

A model can only be as good as the data that is used to develop and calibrate it. The agreement over an acceptable set of hydrologic data that occurred during the development of CALSIM II is a considerable advance. However, there appears to be a need to improve the collection and use of data on water diversions and return flows. Because of the close links between the surface water use and groundwater use there also is a need to have better information on the use of groundwater.

The models used to calculate the Local Water Supplies in the Depletion Study Areas depend on estimates of surface water use, crop evapotranspiration rates and water use efficiencies developed using data from the 1970's. Confidence would be improved if more recent data were available to check these estimates.

- **Calibration**

A very good way to improve confidence in a model is to calibrate it against historical data to ensure that the model output is able to reproduce the observed data. Calibration is the process of using the model to reproduce the historical behavior of the system and then fine-tuning the model so that the match between modeled and observed values improves. The calibration of the model assists in detecting errors in the model and the input data. It also enables a comparison to be made between the way that the operators actually manage the system and the way that the model assumes that the system is managed.

A further consequence of the calibration process is that the statistics of the match between modeled and observed values can be used as a reasonable estimate of the absolute accuracy of the model output.

It is legitimate in a calibration/validation run to incorporate changes to infrastructure, institutional or operational rules as they occurred especially if these changes are specified as

input parameters to the model. This was done to a limited extent in the CALSIM II validation run with three regulatory periods modeled related to decisions made by the State Water Resources Control Board. It is also legitimate to incorporate growth in demand especially if that growth is described in a manner that is consistent with the way that demand is specified in the production run. Demand north of the Delta was specified in the validation run by inputting the historical crop areas.

A Calibration/Validation report should be very useful in demonstrating the accuracy of the model. However there are a number of elements in the CALSIM II validation run and the validation report which reduce that confidence including:

- State Water Project (SWP) demands south of the Delta were set at historical deliveries in years with no restriction and at the contractor's request level in restricted years. Neither of these pieces of information is available to a production run which calculates demand based on crop areas. Therefore the validation run does not provide reliable information on how well the model can represent these demands.
- The validation run omitted Article 21 deliveries. Although this omission will not affect the delivery of 'Table A' volumes south of the Delta, it will affect flow in the Delta and Delta water quality. Also, in the example model run presented in the paper by Draper A.J. et al (2003) which was supplied as part of the review, changes to Article 21 deliveries constituted the largest impact resulting from a change to the allowable pumping capacity at Banks between March and December. This suggests that the modeling of these demands is important.
- The DWR (2003) report produces estimates of SWP and Central Valley Project (CVP) deliveries south of the Delta but then adjusts them for changes in storage before presenting comparisons of those results with observed deliveries. This process merely checks that the model is preserving a water balance and does not present a legitimate validation of model deliveries.
- The report provides statistics on long term average deliveries and flows but no statistics on the fit for individual years. Additional analysis of the output would assist stakeholders to assess whether the estimate of water supply reliability and in particular the modeled volumes of water available in the most restricted years are accurate.
- In some instances, such as the examination of water quality in the Delta, the ability to accurately model monthly flows and deliveries will be important. The validation report contains no information that would enable the ability to model monthly flows to be assessed.
- A key model output is the water quality in the Delta. It would assist the validation of the model if a comparison of parameters such as the location of the X2 boundary was provided.

The users of CALSIM should recognize that models are a summary of what one believes to be true and important about a system. Validation is then an exercise to test how good that summary and understanding really is.

Appendix I contains brief descriptions of calibration modeling in the Murray-Darling Basin in Australia and in the State of Texas.

4.3 Assessment of the reliability of "delivered" water

An important recent application of CALSIM II which has drawn widespread attention is the "State Water Project Delivery Reliability Report. While this is an important step forward in the use of CALSIM for policy purposes, it highlights a number of issues, both conceptual and empirical, that need to be resolved in order to provide a more adequate assessment of the reliability of water supply in California.

First, it illustrates the need for sound calibration of CALSIM. The question being asked is not a comparative one – What are the consequences of changing some aspect of the system from X to Y? – but rather an absolute one – How does the system function at present? How often can users expect a shortage in deliveries of Z%?

Second, it highlights the fact any water system model such as CALSIM requires a blend of hydrology and behavioral analysis. To conduct a water balance, the model needs to know what deliveries are required by the customers of the given project, and what are the diversions by other user groups who extract water from the same surface or groundwater sources. These are fundamentally questions of economic and institutional behavior, not matters of hydrology. Therefore they cannot be dealt with by hydrologists alone. Like its predecessors, CALSIM tends to treat these as black boxes. The diversions by water users outside the CVP-SWP are taken as exogenously given, based on an assumed "level of development" and simplistic assumptions about the patterns of water use associated with that level of development. The deliveries required by the water users who are served by CVP-SWP are generally taken as given. For reasons explained below, both of these treatments are simplistic and unsatisfactory.

In CALSIM modeling exercises the level of development plays two different roles depending upon the context. In a simulation context, the level of development is used to represent hydrologic variability and uncertainty; in a calibration/validation context, it is used to reflect the actual historical demand for water withdrawals. These are very different purposes and it is important to keep them distinct. In most applications of CALSIM prior to the recent reliability study, the main focus was simulation and the representation of hydrologic variability. The chief purpose served by using 73 years of adjusted streamflow records was to represent the variability and uncertainty in the streamflow that one can expect to observe in any single year. Therefore, the calendar date of the record has no substantive significance, the (adjusted) streamflows for 1952 or 1982 are not being used to represented what happened historically in 1952 or 1982, but rather as an indication of the variation in streamflow that could be expected to occur next year, or any other year. In this context of simulating hydrologic variability, it makes good sense to apply the *same* level of development (i.e. the same pattern of water use) to every year in the sequence, rather than a series of different levels of development that vary with calendar time, because the streamflows represent alternative hydrologies that can occur in any given year.[1] The situation is different when one is conducting a calibration or validation

[1] This could be modified to allow for the fact that local weather conditions have a significant impact on irrigation (and urban) demands – e.g., farmers plant fewer acres of crops in a drought year. In that case, one could have different levels of water demand and extraction in different year *types;* but, these would all be keyed to the same overall level of economic development (e.g. the California economy in the 1990s). CALSIM II does not presently

exercise. In that case, one wants to represent the historical demands in 1952 or 1982 in order to compare what the model predicts with what actually happened. Therefore, in a calibration or validation exercise one wants the level of development to change each year in order to reflect the demand that occurred historically.

Both simulation and calibration/validation raise some other important technical issues. In the context of simulation, there are several different ways to generate a hydrologic sequence that is calibrated to a fixed level of development. One can use all 73 years for which data are available. One could use a subset of those years chosen either according to some deterministic rule or randomly. The subset could be oriented, for example, towards the extremes of the 73 sequence of annual records. However, the drawback of any approach based on sampling from the observed historical record is that it *understates* the full variability in streamflow that could be experienced in the future. The 73 years of record are drawings from a probability distribution the extremes of which extend beyond the minimum and maximum flows observed in the historical record. Relying on this record, therefore, understates the true minimum and maximum flows that might be encountered. In a reliability assessment exercise, one might want to take some steps to minimize the potential understatement of streamflow uncertainty. This could be accomplished by fitting a (parametric) probability model to the historical streamflow record and then sampling from the tails of the fitted distribution (Stedinger, 1981). The use of statistical models of streamflow variability could be considered in future applications of CALSIM to assess delivery reliability.

The assessment of delivery reliability requires that particular attention be given to the definition and measurement of the water users' demands. In this context, the user's demands play two roles: they affect the definition of "deliveries" and they influence the assessment of "reliability". With respect to deliveries, CALSIM II considers water to be delivered whenever it has the water irrespective of the ability of a contractor to use the water or to store it; The reality is that, if the contractor does not have a demand for the full quantity of water and is not able to store the excess, that amount will not be delivered. Therefore, the calculation of deliveries would be flawed. Furthermore, reliability cannot be assessed without reference to demand. Stating that a water supply system can deliver 100 acre feet in a wet year but only 70 acre feet in a dry year is useful only if one knows what the demands will be in wet and dry years. The implications are quite different if the user needs 105 acre feet per year than if he or she needs 65 acre feet per year. Thus, the users' demands should serve as the norm against which reliability is assessed. Instead, the recent reliability report uses the so-called 'Table A' water amounts as the norm for assessing deliveries to SWP contractors. This does not seem to be a satisfactory approach because there is no presumption that the Table A amounts, negotiated in 1960, measure the actual demands of SWP contractors in any particular year. The actual demands of the individual contractors will be influenced by how much storage they have, what access they have to other surface water or groundwater, and the demands of the farmers they serve to plant crops and apply water. Without accounting for these factors, it is difficult to generate a meaningful assessment of supply reliability.

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consider the impact of annual weather conditions on demands. In order to model water demands accurately in a year, the climate conditions would be linked to the flow conditions to provide an input set for a particular year.

The assessment of reliability should ideally go beyond a comparison with quantities demanded to incorporate the notion of a loss function. If a user has a demand for 100 acre feet and can only receive 90 acre feet in one scenario and 80 acre feet in another, while the shortfall is twice as large in the second scenario the actual *consequences* of the shortfall to the user, in terms of lost profit or higher cost, might be more than twice as large. To assess the economic value of reliability, or the economic cost of a lack of reliability, one needs to be able translate shortages into monetary losses. To accomplish this, the warning time provided and the delivery shortfalls from CALSIM would need to be processed through an economic model of the value of water to different SWP contractors.

Because water users face difference demands and have access to different sources of supply, when assessing reliability it is unhelpful to aggregate all contractors and simply present the results in terms of total annual project deliveries, as was done in the report. Precisely because of the potential non-linearity of the loss function, a given aggregate shortfall can have different consequences when distributed differently among the individual contractors. A similar observation applies to the temporal distribution of delivery shortfalls across the year. It is unhelpful to aggregate supply system deliveries into an annual total, as done in the report. For a user to be able to obtain 100% of his or her demands in the period from March to May but only 60% in the next three-month period from June to August has different consequences than being able to obtain 80% in each of the six months. Furthermore, for both agricultural users and many urban users, major decisions affecting water use have to be made in the spring. They are based on the expectation around March about the amount of water that will subsequently be available for delivery during the summer months. What matters to these users when assessing supply reliability is the amount of water they can expect around March to be delivered over the summer, rather than the ultimate total delivery.

For both reliability assessment and also model calibration/validation, it is important to avoid excessive aggregation when describing shortfalls between demand and supply, or deviations between model predictions and actual outcomes. In regression analysis, it is the convention to measure the goodness of fit of a regression equation not by the average deviation but rather by the sum of the squared deviations. In ordinary least squares regression, by definition the average deviation is always zero (that is to say, the average of the predicted values of the dependent variable always equals the average of the actual values) regardless of how well or badly the regression equation fits the data. The average deviation thus provides *no* information regarding the goodness of fit; by contrast, the sum of squared deviations or the sum of the absolute values of the deviations are sensitive measures of goodness of fit. Although the calibration of CALSIM is not an exercise in least squares regression, the same general principle applies. To judge whether the model is doing a good job, the goodness of fit should be measured by reference to the disaggregate results and not simply by the overall average deviation.

Additional comments on the 2003 CALSIM II Validation Report are contained in Appendix F.

5. Managing CALSIM Development and Applications

The costs of not continuously and substantially improving our analytical capabilities are political (in terms of continued controversy and diminished agency credibility), economic (as inferior system performance for agricultural and urban water users), environmental (in terms of inferior environmental system performance), and financial (lawyers and policy consultants are more expensive than engineers and scientists).

CALSIM II is a substantial improvement over its predecessor models, DWRSIM and PROSIM, with a great deal more flexibility, transparency, and potential than these earlier models. The modeling team for CALSIM has identified an exciting and relevant vision of how modeling should be done for this complex and difficult system in the coming years. However, implementation of this vision in a coherent technical manner that leads to both technical and stakeholder credibility will be a difficult process, requiring financial and institutional support if this kind of capability is to be developed and sustained.

To accomplish these objectives CALSIM II developers need to be in an institutional position where they can see the model more as "outsiders" view it. This would allow them to be more responsive in supporting the credibility of their work and the relevancy of their tools and results to the broad range of current water management problems. As such CALSIM II should no longer be solely responsible to CVP-SWP managers, but should be responsible to a broader range of technical managers from additional interests, reflecting its current and prospective uses.

It would be imprudent to manage a state's finances, a business, or a retirement plan without quantification – quantification in such matters is necessarily imperfect, but necessary nonetheless. While shortcomings have been identified in CALSIM II, it would be similarly irresponsible to manage California's water budget without carefully-interpreted quantification. Progressive and continuous improvement in our quantitative understanding of California's water system provides a common basis for improving its performance for all interests.

One possible means of maintaining control of the quality of particular versions of CALSIM II and accompanying models used for SWP-CVP planning and management decisions is to create an interagency modeling consortium (IMC) consisting of DWR, USBR, and persons from other stakeholder organizations if they are interested and want to participate. This consortium would be responsible for maintaining a toolbox of 'acceptable' models for 'official' use by the agencies and contractors.

IMC responsibilities and authority could include:

- Prioritize, coordinate, and provide consistency, technical guidance and oversight for all modeling applications,
- Approve model selection and insure that each requested application is carried out using the most appropriate model(s) and input data,
- Provide or otherwise insure documentation of the modeling process itself as well as the modeling results,

- Insure that the results are expressed and made available in a way such that others can understand and benefit from that modeling application, as applicable.
- Implement peer reviews of models and their applications as deemed appropriate.

To help meet their responsibilities the IMC will need to establish, publish and implement some procedures for insuring the quality of the entire model development and application process. They will need to identify among all the models that might be used, which are the most appropriate to address each of these separate groups of model applications. They must identify various models, i.e., establish a model toolbox, from which clients can choose the one that best meets their needs (or perhaps argue that another model should be added to the toolbox). The IMC will also need to maintain model documentation and provide for peer reviews of any model, its documentation, and/or its use in a project.

Further suggestions and discussion on the creation and operation of a possible IMC for model development and application, as well as for managing peer reviews of both the models and their applications, are contained in Appendix E.

6. Recommendations for Future Use, Development, and Application of CALSIM II

The most concise recommendation we might make would be to fix the shortcomings beginning with what are considered the most serious, and proceeding to those that are less serious, taking into account the time and other resources needed to address each weakness. However, we believe it is more useful to suggest ideas on how to systematically address both present shortcomings and those likely to emerge as stakeholders' quantitative understanding of California's water system and its problems continue to evolve.

6.1 Model development and support consortium

As discussed in the previous section and in Appendix E, it might be useful to explore creation of a broader interagency modeling consortium for developing operations planning models for California. The joint DWR-USBR development strategy used for CALSIM II has shown some notable successes, and should be expanded to include additional parties and sources of expertise. Such a consortium might include staffs from several agencies (DWR and USBR, as well as potential members from MWD, KCWA, CCWD, and other agencies), NGOs, some consultants, and universities. Such a model development forum would:

a. Bring a wider range of expertise to bear on model development problems.
b. Facilitate having more agencies involved in supporting model development with expertise and financial resources.
c. Better enable model developers to see the model as "outsiders" see it.
d. Potentially improve contracting for model development and testing.

e. Take model development and testing outside of the explicit agency framework; a broader consortium should be more conducive to self-critical and transparent technical practices.
f. Provide a common training ground for agency, NGO, and consulting staffs to become effective modelers, broadening the talent base for technical work in California.
g. Reduce impediments to model development and testing arising from current State budgetary and personnel hiring problems.

Many of the questions, concerns, and problems mentioned in the user community interviews could be addressed well in such a distributed model development, testing, and support framework. It would still be necessary for each stakeholder group and agency to maintain its own modeling staff, but these would be partially shared in an interagency modeling consortium.

The governance and finance of such a consortium would be difficult and would probably require a steering committee or governing board, but any resulting model(s) would have broader credibility and a broader and deeper technical base.

In the immediate term, a users' group should be formed and the formal listing of model development activities should be posted on the web, including short descriptions of each development activity and contact information.

6.2 Quality Control Program

The DWR and USBR modeling team (or a broader model development consortium) need an explicit quality control program. Such a program should include a variety of activities:

a. periodic external reviews on the broad modeling program
b. specialized external reviews of model products and applications
c. a standing (or sitting) external technical advisory body
d. software engineering and maintenance
e. a regime of model testing
f. model and data documentation
g. data development and management
h. user group activities
i. local agency and interest involvement
j. model, data, and documentation accessibility (including web site use).
k.

Such a quality control program would benefit from deep consultation with stakeholders and the broad community of water technical people, perhaps via the California Water and Environment Modeling Forum (www.cwemf.org).

6.3 A Training Program

DWR, USBR, and assorted agencies and consultants should establish a more formal common regimen to train new CALSIM II users in both CALSIM software and the complexities of actual system operation. All these groups currently rely on a relatively small pool of perhaps a

dozen knowledgeable CALSIM II users and all proclaim a need for many more capable users. A training regimen consisting of current CALSIM II training classes, supplemented by additional training in software application and system operation and apprenticeships or rotations through operations and model development shops would be useful to all concerned. The entire water community would benefit from having such expertise being widespread. Having widespread CALSIM II modeling expertise also makes explaining CALSIM II and its results easier. This might be an appropriate activity for a model development consortium.

6.4 Extend Improvements in Modeling Practice to Supporting Models

CALSIM II is at the center of a web of additional models used by DWR, USBR, and other agencies to prepare inputs for CALSIM II and post-process outputs from CALSIM II.

Delta controversies and difficulties of representation seem endemic to problems of modeling Central Valley operations. The technical basis for representations of Delta operations and water quality performance requires a similar level of transparency and testing to avoid this becoming a "weak link" in the Valley-wide operations planning model. Since so much is based on the DSM2 Delta model, documentation of fairly strenuous tests of the DSM2 model are highly desirable. This would provide a firm foundation for the use of ANN or other approaches for summarizing DSM2 behavior in an operations model. Similar documentation, testing, and development are desirable for the other models mentioned above which provide data for CALSIM II (CVGSM/IGSM, CVPM/CALAG, IWR-MAIN, LCPSIM, CU model, and SIMETAW).

6.5 Hydrologic Data and Data Development

An effort should be made to step back and perhaps re-define a more systematic and solid basis for developing hydrology for water management models of California's inter-tied water system. Currently, several efforts exist to develop surface or groundwater hydrologies for parts of the Central Valley (sponsored by DWR-USBR, USACE-Sacramento District, USEPA, USGS, CALFED, local agencies, etc.). An effort should be made to broaden the range of hydrologic expertise involved in hydrology data development for management modeling of California's inter-tied water system, and establish a consistent and high, but reasonable, standard of documentation and testing for developed data and any underlying hydrologic models. Establishing such a standard of documentation and testing would make existing hydrologic studies more accessible and useful for future studies and encourage the comparison and further development of existing representations of the system's hydrology.

6.7 Performance-Based Optimization

Performance-based optimization should be added to CALSIM's capabilities; it would not be difficult in terms of software or data, and would add much greater ability to explore and seek improvements in management within a complex system. The multi-period optimization approach being developed (CAM) is an operations-oriented first step in this direction, but could be expanded without great difficulty.

For large-scale water resource systems of great complexity and many options for system management, it is often difficult to find "optimal" operations with simulation modeling. There are simply many myriads of decision options and combinations of options, which theoretically each require a simulation model run – which would be prohibitive in terms of analysis cost and time. In such situations, performance-based optimization models, such as those seeking maximum economic performance, can offer useful insights as to where to look for improving system operations and management. Metropolitan Water District of Southern California (MWD) and San Diego County Water Authority (SDCWA) employ performance-based optimization modeling of parts of California's water system to gain strategic insights for planning and management. An economic-engineering optimization model has been developed for California and, despite significant limitations, shows several insights for California (CALVIN), suitable for identifying promising operational and management strategies worthy of more detailed analysis (Jenkins et al. 2001; Draper et al. 2003; Jenkins et al. 2004). The CALSIM II modeling approach could easily be adapted to provide greater functionality to this type of performance optimization. Having performance-based optimization capability together with a compatible simulation model for more detailed analysis and trade-off evaluation could greatly improve the capability of California's water community to explore and develop promising and creative options for improving operations, facilities, and overall system management.

6.8 Modular and Layered Versions of CALSIM II

Speedier versions of CALSIM II are needed for operations planning and integrated water planning studies. Such versions would be regional modules of CALSIM II (for regional studies) or explicitly aggregated system-wide models from the most detailed CALSIM II schematic for system-wide or statewide studies. Both approaches would simplify the model for particular purposes, yet be tied to a common detailed schematic and detailed hydrologic, operations, and water demand data sets.

Geographically modular or aggregated system-wide versions would allow additional local and regional water management options to be represented for particular operations and policy planning purposes and allow users to more quickly explore and develop operating policies. The final runs from such integrated or exploratory studies could then be evaluated using a more detailed and complete version of CALSIM II.

Modular regional models might represent regions with relatively few inter-ties, such as: Sacramento Valley, Delta and eastside streams, San Joaquin Valley, San Francisco Bay Area, Tulare Basin, and Southern California (DWR's South Coast and Colorado River hydrologic regions). (We have had good success with the CALVIN model of California with 5 modular regional models, which combine to form a system-wide model. These geographic sub-models greatly improved quality control in model development, work flow and data checking, and identification of problems in the model.)

6.9 Model Calibration and Testing

Many approaches exist for model calibration and testing (Modeling Forum 2000). Calibrating a planning model oriented to operations in an uncertain and distant future is always challenging. For a model that serves many uses (including policy-urgent uses unforeseen by developers), use-specific testing will often be impossible within a responsive time frame and budget. Such unavoidable situations call for more thorough, general, and well-documented model calibration and testing than would otherwise be needed.

For the model to have technical credibility, stakeholder credibility, and to serve the kind of training and reference function needed for the water management community, a systematic and coherent means of setting parameter values in the model and documenting these values is needed. Similarly, a systematic self-critical means of testing is needed for a model to establish and retain credibility, and have defined limitations, for a range of applications.

A potentially excellent resource for model testing is comparisons of seasonal operations planning CALSIM II model runs with recent years' seasonal operations, as done by actual operators. Similarly, system operators could scrutinize historical simulations, such as those in the recent November report, for systematic differences from operating practice. Such comparison with operator policies and philosophy could also be performed with SWP or CVP delivery reliability estimates. Such comparative analyses would both help define the likely (and unavoidable) differences between actual and modeled operations and water deliveries and identify potential opportunities to narrow such differences.

Credibility arises, in part, from demonstration that problems and limitations are systematically identified and addressed or considered in model development and in making and interpreting model runs. This can be accomplished by use of documentation, metadata, written guidance, and protocols and logs for identifying model problems and recording model improvements.

Given present and anticipated uses of CALSIM II, the model should be calibrated, tested, and documented for "absolute" or non-comparative uses. This is what many applications require today and will be increasingly desired and required in the future. Maintaining the traditional "comparative-only" use of CALSIM II is undesirable if the model is to be useful for the CVP and SWP systems, the operations of water contractors, or for statewide planning purposes.

6.10 Documentation of Model Improvements

Along with better documentation of model versions, logs of data and model improvements and "bug fixes" should be maintained. Explicit protocols and records for identifying and correcting modeling errors and problems would enhance the credibility of the modeling effort with technical people and policy makers. Such protocols also provide an internal aid to staff and staff development in modeling. I understand that this kind of record-keeping is done, but the precise form of, nature, and extent of this record-keeping is unclear. It would be useful and reassuring to stakeholders and policy makers to know that this kind of record-keeping of the software and data was being done.

6.11 Better Model Integration in Decision-Processes and Stakeholder Education

Greater aid should be given to interested parties and decision-makers who must work with the unavoidable limitations of any model. If possible, a document should be prepared for stakeholders and interested parties outlining the model, summarizing the model's primary limitations, and providing guidelines for interpreting model results. Those developing policy-making forums and processes should thoughtfully incorporate computer models in these processes in ways that do not assume model omniscience, or otherwise place too great or exclusive a reliance on model results.

Models and model results will never be perfect. If models are to be important for planning and policy-making, they be must be presented and used in ways that enlighten policy-makers more than they add confusion and controversy to already difficult situations, if possible.

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Appendix A: CALSIM II Science Review

Dates: Nov 13-14th
Location: Bay-Delta Room, CBDA Offices
650 Capitol Mall, 5th Floor
Sacramento, CA

Day 1: The Management Context, Model and Application Details

9:00 Welcome – Kim Taylor
- Overview of the CALFED Bay Delta Program -
- Introduction of the Panel

9:15 Water issues in California – Francis Chung
- General Hydrology
- SWP/CVP
- Operational challenges
- Sacramento-San Joaquin Delta – Ron Ott (5 min.)

9:35 Panel Q&A

9:45 Planning Models – Andy Draper
- CALSIM software
- CALSIM II application overview
- Interaction with other models

10:10 Panel Q&A

10:20 Break

10:30 Summary of CALSIM Applications
- DPLA/CalFed/US Bureau of Reclamation: Integrated Storage Investigations – Steve Roberts
- Bay Delta Office (DWR): SWP Delivery Reliability Report - Kathy Kelly
- USBR: Multi-layered modeling to simulate CVPIA (b)(2) water and Environmental Water Account Operations – Nancy Parker
- Operations Control Office (DWR): Oroville Relicensing, SWP Allocation decision procedure – Curtis Creel
- Department of Planning and Local Assistance (DWR): California Water Plan Update – Kamyar Guivetchi/Ken Kirby

12:15 Panel Q&A

12:30 Lunch

1:15 Summary of User and Stakeholder Interviews
- 1:15 Interview Summary and Findings – UC Davis
- 1:35 Panel Q&A
- 1:50 Public Comment

2:15 CalSim II Details
- Development philosophy – Francis Chung
- Operation priorities, constraints, common assumptions – Erik Reyes
- Hydrology development – Andy Draper
- Delta water quality constraints – Ryan Wilbur

3:15 CalSim Evaluation
- Historical Operations Study / Sensitivity Analysis – Sushil Arora

3:30 Panel Q&A

3:45 Break

4:00 Future Directions
- Data Structure / Version Control / Multi-Period Prescriptive Optimization – Ryan Wilbur
- Daily Time Step - Dan Easton
- CalSim II – CVGSM Integration – Tariq Kadir
- Water Quality / Upstream Models – Nancy Parker

5:00 Panel organizational meeting (additional information needs, questions of specific staff, discussion plan)

Day 2—Panel Deliberations and Preliminary Report

8:30 Panel Q&A with specific DWR and USBR staff on request

9:30 Panel *in camera* discussions

11:00 Panel presentation of draft main findings—Pete Loucks

12:00 Wrap up and next steps - Kim Taylor

Appendix B: Briefing Material for CALSIM II Peer Review

California Water
Averting a California Water Crisis (3 pages)
California Water Today, Bulletin 160-0, Chapter 2 (20 pages)
Water Supplies, California Water Plan Update, Bulletin 160-98, Chapter 3 (11pages)
Urban, Agricultural and Environmental Water Use, California Water Plan Update, Bulletin 160-98, Chapter 4 (17 pages)
California's Major Water Projects (map) (1 page)

CVP and SWP
State Water Project Operations (6 pages)
Central Valley Project Operations (16 pages)

CalSim and CalSim II Overview
CalSim: A Generalized Model for Reservoir System Analysis (19 pages)

CalSim Software Details
CalSim water resources simulation model: Users guide (18 pages)
CalSim water resources simulation model: Wresl language reference (11 pages)

CalSim II Details
Network Representation (1 page)
Sacramento-San Joaquin Delta Operations (9 pages)
Coordinated Operating Agreement (3 pages)
Reservoir Rule Curves (2 pages)
CalSim ANN Implementation (8 pages)
CVPIA (b)(2) Management and Operations (6 pages).ii
EWA Management and Operations (8 pages)
Multi-Cell Groundwater Model (2 pages)
SWP and CVP Delivery Allocation Logic (3 pages)

Hydrology Development
Surface Water Hydrology Development for CalSim II (8 pages)

Supporting Computer Models
Model Interaction (1 page)
CALAG (2 pages)
CU Model (2 pages)
DSM2 (2 pages)
IGSM2 – CVGSM (4 pages)
LCPSIM (5 pages)

CalSim II Evaluation
Planned Sensitivity Analysis (7 pages)
CalSim II Simulation of Historical SWP-CVP Operations - Extracts (61 pages)

CalSim II Applications
CalSim II Project Applications Summary (not completed)
SWP Delivery Reliability Report – Extracts (25 pages)
North of Delta Offstream Storage Investigations (3 pages)
In-Delta Storage Investigations (3 pages)
California Water Plan Update 2003 (3 pages)
CalSim II and SWP Operations Control Office (1 page).iii

Future Model Development

(a) CalSim Software
CalSimMulti-period Prescriptive Optimization (not completed)
CalSim Daily Time Step Model (not completed)
CalSim Water Quality Module (not completed)
Data Structure / Version Control (not completed)
CalSim Graphical User Interface (not completed)

(b) CalSim II Applications
CalSim II – CVGSM Integration (not completed)
CalSim II Geographical Expansion (not completed)
Global Climate Change (not completed)
Refined Spatial Resolution (not completed)
Expansion of Land Use Based Demands (not completed)
CalSim II – CALVIN Integration (not completed)
Revision of Urban Water Demands (not completed)

(c) Supporting Models
Replacement of Consumptive Use Model (not completed)

Appendix C: CALSIM II Review Process and Timeline

Establishing the Peer Review Panel

Dr. Pete Loucks (Cornell University and South Florida Water Management District) has accepted the CALFED Science Program's invitation to chair the panel. Other members are being currently being contacted by the Science Program staff

Organization of Briefing Material

Science Program and key agency staff, in consultation with the review panel chair, are identifying and organizing briefing material for panel members. Target date for completion is Sept 1, 2003. (This was extended to December 8, 2003)

Public Meeting of Review Panel

Target: 2-day session in November, 2003 in Sacramento area

Review workshop structure will include:

- Presentation overviews of California hydrology, water management, current issues, and the development of CALSIM II
- Presentations on the range of different current and potential applications of CALSIM for planning, operations, and supply reliability projects
- A summary of an independent interview project by Dr. Jay Lund of users and stakeholders explaining the major questions people are trying to answer with CALSIM II and other models
- Public comment to the panel
- Detail discussion of the model, including assumptions used in different applications, verification studies, and sensitivity analyses
- Opportunity for panel members to ask follow up questions of CALSIM developers and users
- An in camera session for panelists to discuss and begin compiling review comments
- A public presentation of the panel's draft findings

Panel Chair Provides Final Report to CALFED Lead Scientist

The panelists will be asked to finalize their review comments within 3 weeks of the public meeting and to transmit those directly to the Lead Scientist. The Science Program will transmit the completed review to CBDA and the CALFED community.

Appendix D: Panelists CALSIM II Review, Nov. 13-14, 2003

Name	Affiliation	Position	Address/Phone/E-mail
Andy Close	Murray Darling Basin Commission	Lead Modeler and System Manager	GPO Box 409 Canberra ACT 2601, AUSTRALIA (02)62790102 andy.close@mdbc.gov.au
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John Labadie	Colorado State University	Professor	B211 Engineering, Fort Collins, CO 80523 (970)491-6898 John.Labadie@colostate.edu
Pete Loucks	Cornell University	Professor	"Civil and Environmental Engineering, 311 Hollister Hall, Ithaca, NY 14853 " (607) 255-4896 DPL3@cornell.edu
Jay Lund	UC Davis	Professor	Civil and Environmental Engineering 3109 Engineering III, Davis, CA 95616" (530)752-5671 jrlund@ucdavis.edu
Daene McKinney	University of Texas at Austin	Professor	Civil and Environmental Engineering Campus Mail Code: C1786, Austin, TX 78712 (512)471-8772 daene_mckinney@mail.utexas.edu
Jery Stedinger	Cornell University	Professor	Civil and Environmental Engineering, Hollister Hall, Ithaca, NY 14853 (607) 255 2351 JRS5@Cornell.edu

Appendix E: Managing Model Development, Application, Documentation and Communication.

One possible means of maintaining control of the quality of particular versions of CALSIM II and accompanying models used for SWP-CVP planning and management decisions is to create an interagency modeling consortium (IMC) consisting of DWR, USBR, and persons from other stakeholder organizations, including NGOs and universities, if they are interested and want to participate. This consortium would be responsible for maintaining a toolbox of 'acceptable' models for 'official' use by the agencies and contractors.

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- Insure that the results are expressed and made available in a way such that others can understand and benefit from that modeling application, as applicable.
- Implement peer reviews of models and their applications as deemed appropriate.

To help meet their responsibilities the IMC will need to establish, publish and implement some procedures for insuring the quality of the entire model development and application process. They will need to identify among all the models that might be used, which are the most appropriate to address each of these separate groups of model applications. They must identify various models, i.e., establish a model toolbox, from which clients can choose the one that best meets their needs (or perhaps argue that another model should be added to the toolbox). The IMC will also need to maintain model documentation and provide for peer reviews of any model, its documentation, and/or its use in a project.

CMM Level 3 Performance Expectations

Firms that develop professional software are typically required to meet certain software standards. One such standard is defined in a book from Carnegie Mellon University. These so called Capability Maturity Model (CMM 1994) standards have various levels. For example, the South Florida Water Management District, that develops hydrologic models used as inputs to major investment decisions, strives to meet Level 3 standards. To meet such standards in software development and peer review, one needs to show that

- Modeling related problems are anticipated and prevented

- Model development and application groups work together as an integrated product team.
- Model use training is planned and provided as is needed.
- New modeling methodologies are identified and evaluated for possible implementation on a qualitative basis.
- Data are collected and used in all defined processes.
- Data are systematically shared across various projects.
- Both the models and their applications are evaluated and judged satisfactory by independent reviewers.

It seems to this panel that CALFED could without too much difficulty meet such standards if it chose to. Clearly planning for, conducting, and documenting these activities will require additional time and money. The expectation is that in the long run, such documentation and review will save time and money by redirecting misguided initiatives, identifying alternative approaches, or providing valuable technical support for a potentially controversial decision.

Model Toolbox

The IMC in collaboration with all agencies involved in water resources planning could be responsible for creating and maintaining a collection of models that agencies can use to meet their needs. As shown in Figure 1, this collection of models might be called the model toolbox. The criteria to be used as a basis for deciding whether a proposed model should or should not be included in the toolbox will depend in part on an assessment of the attributes of that model compared to alternative models and the suitability of the model to meet the needs of the project. Associated with the model toolbox is a library of completed model application documents and data bases for use by anyone who could benefit from them.

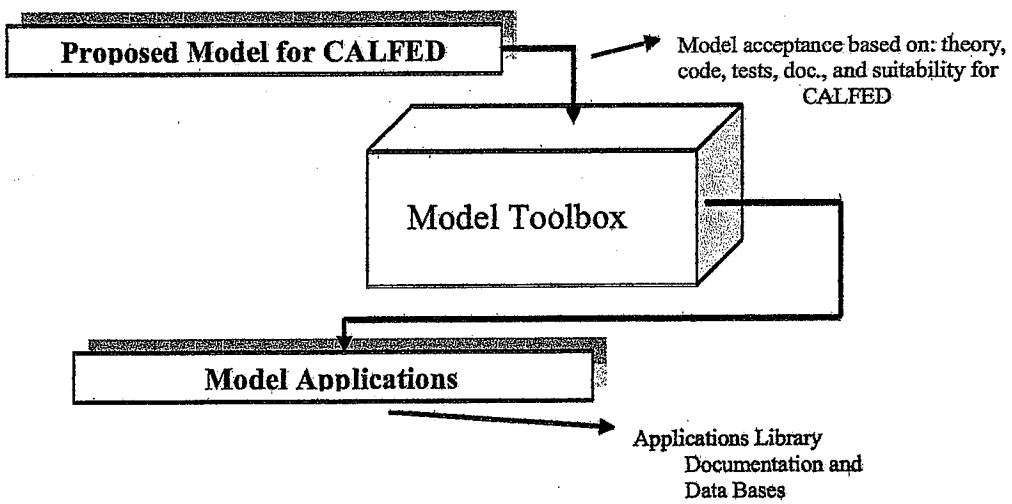

Figure 1. Model Toolbox consisting of approved models for use and Applications Library consisting of documentation and model data bases.

Everyone would agree that all modeling applications should be performed with the 'best' models available. But 'best' does not mean that all models used should be the most detailed, complex, realistic and thus usually the most expensive models available. The decision regarding the 'best' or most appropriate model should be based on the particular issues or questions being addressed, on the quantity and quality of the available input data, and on the time, personnel, and money available to perform the modeling application. The central question to be answered before initiating any modeling application is just what model output information (and precision) is needed to meet the needs of the decision making process. Expressed in other words, just how sensitive will the decision be to the type, amount and precision of the model output?

IMC in consultation with the other agencies could provide guidance on the adequacy of a particular version of CALSIM II or other associated model requested by each client with respect to the theory upon which it is based, its data requirements, its spatial and temporal resolutions, its documentation and status with respect to peer reviews, its capabilities, and its limitations. Similar considerations must be given to the proposed input data. To provide these services to each client requesting services from the IMC would require IMC to be staffed with personnel acquainted with the models in the toolbox, as well as be able to perform or review the simulations requested by various agencies.

There will likely be requests to use models not yet included in the model toolbox. IMC together with others from the DWR and/or USBR will need to judge the merits of such requests and if deemed beneficial, consider including such models in the toolbox. Undoubtedly the extent and quality of the documentation, testing, and peer review of various models in the toolbox will vary. However, a model's inclusion in the toolbox should signify that the model has been judged to be the best available for meeting the goals for which it was designed and is applicable to conditions in California.

Information Flows and Documentation

The IMC will probably be devoting a substantial amount of time giving guidance to clients and, when applicable, to the public. They will need to be working with the clients who are requesting model applications, and in situations where they are not doing this work, they will need to be reviewing and approving the work of the agencies or contractors who are performing the modeling services. IMC would provide technical assistance as well as oversight and coordination among all CALSIM II modeling activities.

Requests for modeling are easy to make, and time and money are required to carry them out. Requests sent to this proposed IMC should reflect some thought by those requesting such model runs as to just why the model application is desired, and just how the results are to be used. We would propose that requests include such items as:

- Reason for modeling,

- Type of modeling (e.g., event based or continuous),
- Particular model preference if any, and why, and possible alternatives,
- Model output information (data) needed and why and when it is needed,
    - What questions are the model results going to answer?
    - What issues are being studied?
    - What decisions are to be made, or at least to be informed, based on these model results?
    - When are the model results needed?
    - What formats are desired for presenting the model results?
- Location or site being modeled and the spatial and temporal scales desired,
- Particular input data assumptions, boundary conditions and other regional assumptions required,
- Source of input data, and format required or desired for the output data,
- Model calibration and verification needs and preferred procedures if any,
- Money and time available for modeling,
- Extent (duration) of the simulations to be performed,
- Desired performance measures, other than variables being simulated, if any,
- Alternative scenarios to be modeled (i.e., number of simulation runs needed),
- Other analyses or model applications that may or will need the output from this model application,
- Sensitivity and uncertainty analyses needed, and for which decision variables and why,
- Client contact person,
- Requirements for intermediate reviews of results or needs for periodic review of modeling application process logs and documents, and
- Other particular requirements or needs.

The use of a model nearly always takes place within a broader context. The model itself can also be part of a larger whole, such as a network of models in which some are using the outputs of other models. These conditions may impose constraints on the simulation modeling project. All these considerations need to be specified in the modeling application request.

Along with the proposal, there should also be a simple order-of-magnitude estimate of the expected values of all relevant decision variables based on simple mass-balance analytical solution methods that can be used without requiring a computer. These estimated values should be used to validate (check the reasonableness of) selected portions of the model runs. If there are any serious discrepancies, it may signify a major problem in the model output.

Is all this paperwork useful? It is to the extent it leads to a more effective and efficient use of personnel, money and time. Preparing a formal modeling application request requires some serious thought as to just why this is necessary and just what information is needed to further the project or analysis. It involves defining the objectives that are to be accomplished. Writing this down in some detail helps reduce the differences in perception that can exist between those who need information and those who are going to provide that information (IMC or a contractor). The problem as stated is often not the problem as understood, by either

the client or the model user. In addition, problem perceptions and modeling objectives can change over the duration of a project. One should ask and answer the question of whether or not modeling in general is the right way to obtain the needed information. What are the alternatives to modeling?

The objective of any modeling project should be clearly understood with respect to the domain and the problem area, the reason for using a particular model, the questions to be answered by the model, the model assumptions and limitations, and the scenarios to be modeled. Throughout the project these objective components should be checked to see if any have changed and if they are being met.

If IMC is to serve as a central point to coordinate CALSIM II-related modeling activities, and to provide modeling services, it needs to have the authority to do so. This authority extends to giving advice on issues related to model and input data selection, and for reviewing, approving and prioritizing requests for services. Should contractors be involved in particular model applications, IMC must be authorized to specify the technical terms to be met and oversee the work done by the contractor. Finally IMC will need the financial and human resources needed to do this in a timely manner.

Modeling Application Documentation

One common problem of model studies once they are underway occurs when one wishes to go back over a series of simulation results to see what was changed or why a particular simulation was made or what was learned. It is also commonly difficult if not impossible for third parties to continue from the point at which any previous modeling project was terminated, especially if some time has passed. These problems are caused by a lack of information on how the study was carried out. What was the pattern of thought that took place? Which actions and activities were carried out? Who carried out what work and why? What choices were made? How reliable are the end results? These questions should be answerable if a model journal is kept. Just like computer programming documentation, modeling project documentation is often neglected under the pressure of time and perhaps because writing it is not as interesting as running the models themselves.

The paper trail of what has happened, what assumptions have been made, how calibration and verification were carried out, what results were obtained, why changes, if any, were made, what sensitivity analysis procedures were used and their results, and so on, could be contained in a modeling application documentation (MAD). Once the model application is completed, a copy of the MAD should be given to the requesting agency, as applicable and a copy should remain in IMC. These reports, or at least a summary of them, should be available for downloading from the web. Should further model applications be requested and approved, the requester as well as the IMC can refer to this previously prepared documentation to better understand what was done previously that pertains to the current request.

Model Calibration

Once a model is tested satisfactorily, it can be calibrated. Calibration of models such as CALSIM II are difficult because there are no historical observations of future scenarios to compare with model results. Historical runs, such as have been made, can provide some basis for calibration. In general the smaller the deviation between the calculated model results and the field observations, the better the model. This is true to a certain extent, as the deviations in a perfect model are only due to measurement errors. In practice, however, a good fit is by no means a guarantee of a good model.

The deviations between the model results and the field observations can be due to a number of factors. These factors include possible software errors, inappropriate modeling assumptions such as the (conscious) simplification of complex structures, neglecting certain processes, errors in the mathematical description or in the numerical method applied, inappropriate parameter values, errors in input data and boundary conditions, and measurement errors in the field observations.

To determine whether or not a calibrated model is a 'good' predictor, it should be validated or verified. Calibrated models should be able to reproduce field observations not used in calibration. Validation can be carried out for calibrated models if an independent data set has been kept aside for this purpose. If all available data are used in the calibration process in order to arrive at the best possible results, validation will not be possible. A decision to leave out validation may be a justifiable one especially when data are limited.

Philosophically it is impossible to know if a simulation model of a complex system is 'correct'. There is no way to prove it. Experimenting with a model, such as by carrying out multiple validation tests, can increase confidence in that model. After a sufficient number of successful tests, one might be willing to state that the model is 'good enough', based on the modeling project requirements. The model can then be regarded as having been validated, at least for the ranges of input data and field observations used in the validation.

If model predictions are to be made for situations or conditions for which the model has been validated, there may be some confidence in the reliability of those predictions. Yet one cannot be certain. Much less confidence can be placed on model predictions for conditions outside the range for which the model was validated.

While a model should not be used for extrapolations as commonly applied in predictions and in scenario analyses, this is often exactly the reason for the modeling project. What is likely to happen given events we have not yet experienced? A model's answer to this question should also include the uncertainties attached to these predictions. Depending on the type of model selected and used, one might end up predicting an incorrect future with great accuracy, or predicting the correct future with great uncertainty'. We don't yet know how to predict the correct future with great accuracy – so we do 'what ifs'. One can then argue about what scenarios – the ifs – are the most reasonable or probable, or about the impacts from improbable scenarios that you want to avoid should such scenarios occur.

Use the model

Once the model has been judged 'good enough,' the model may be used to obtain the information desired. Close communication between the client and the modeler during the modeling application process is essential to avoid any unnecessary misunderstandings about what information is wanted and the assumptions on which that information is to be based.

Before the end of this model-use step one should determine whether all the necessary simulations have been performed and whether they have been performed well. Questions to ask include

- did the model fulfill its purpose?
- are the results valid?
- are the quality requirements met?
- was the discretization of space and time chosen well?
- was the choice of the model restrictions correct?
- was the correct model and/or model program chosen?
- was the numerical approach appropriate?
- was the implementation performed correctly?
- what are the sensitive parameters (and other factors)?
- was an uncertainty analysis performed?

If any of the answers to these questions is no, then the situation should be corrected. If it cannot, the reason(s) for why it cannot be corrected should be documented in the model application document (MAD).

Interpret model results

Interpreting the information resulting from models is a crucial step in the modeling application process, especially in situations in which the client may only be interested in those results and not the way they were obtained. The model results can be compared to those of other similar studies. Are the results consistent? IMC must make that judgment. Any unanticipated results should be discussed and explained. The results should be judged with respect to the modeling project objectives.

The results of any modeling project typically include large files of time-series data. Only the most dedicated of clients will want to read those files. Thus these data must be presented in a more concise form. Statistical summaries should explicitly include any restrictions and uncertainties in the results. They should identify any gaps in the domain knowledge, thus generating new research questions or identifying the need for more field observations and measurements.

Report model results

Once the modeling application is completed, the organization doing the modeling will be responsible for preparing a report. The contents of this report should conform to the agreement

made between modeling organization and the client prior to the initiation of the modeling application (see above). Although the results of a model are very rarely used as the sole basis for policy decisions, those requesting model applications may have a responsibility to translate their model results into policy recommendations. Policymakers, managers, and indeed the participating stakeholders typically want simple and clear unambiguous answers to complex questions. Much of the scientifically justified discussion, say regarding the uncertainties associated with some of the data, included in the main body of a report are not included in the executive summary of that report. This executive summary is often the only part read by those responsible for making decisions. Therefore, the conclusions of the model study must not only be scientifically correct, but also concisely formulated, without jargon, and fully understandable by managers and policymakers. When preparing or reviewing contractor model results reports, the IMC should consider this need.

These model application and model results reports should include sufficient detail to allow others to reproduce the model study (including its results) and/or to proceed from the point where this study ended. The report therefore requires a clear indication of the validity, usability and any restrictions of the model results.

Data Management

CALSIM II and its associated or linked models will require data. They will also produce data. Many of these data will have spatial and temporal dimensions. This information must be documented (meta data), preserved, and made accessible to IMC customers, coordination agencies and others. IMC should participate in data management strategic development, storage, documentation and dissemination. It should work with data base managers of various agencies to help them satisfy the IMC's data management requirements.

The availability of quality assured data is a critical dependency that must be met to facilitate timely completion of model development, implementation and application. To mitigate the impact of the availability of data on the timeline for the major model completion deadlines, the following issues should be addressed. :

- Updating land use / land cover data at regular and timely intervals.
- Developing and maintaining a common modeling database. This data base should include infrastructure design and operating policy data as well as water quality, ecological, land use, economic and of course hydrological data. Many of these data sets will have spatial as well as temporal dimensions. Each data set should have an associated metadata file.
- Pre-processed and post-processed datasets from previous model runs should be archived along with its metadata file in a central location for ease of access and availability.
- Measures to insure the consistency and quality of the input data.
- Measures to insure adequate communication among model developers, users and stakeholders. This includes measures to assist in developing documentation appropriate for each type of stakeholder.

Support of IMC activities

Common failures of IMC type organizations are typically due to:

- Insufficient staff to enable cross-training. This may lead to the dependency on one person or a very small group of employees for each sub module or the overall effort.
- Inadequate funding to institute good project management discipline.
- Inadequate funding to contract for technical writers and software engineers.
- Inadequate funding to contract for peer reviews.

Risk assessments

A risk assessment of CALSIM II and its associated models and data should be completed. The timely availability of quality assured data for example, is a risk. Project risk management includes the processes concerned with identifying, analyzing, and responding to uncertainties. Risk management attempts to minimize the results of adverse events. As a guide, the template, such as shown at the end of this Appendix, may be used to facilitate the assessment of risks.

Problem Management

Given the high visibility and criticality of the CALSIM II modeling effort an issue or problem management process should be developed within IMC. Issue/problem management includes the process for identifying, communicating, and resolving issues and problems.

The purpose of this procedure is to ensure that:

- Issues are identified, reported, managed, and resolved in a timely and effective manner. Responsibility is assigned to an owner for reporting, managing and resolving each issue
- All affected stakeholders are aware of the status of the issues
- Escalation of unresolved issues take place according to a defined procedure

In order to ensure that project issues and problems are appropriately managed various issue/problem management steps should be identified and followed to track the actions taken to resolve the issue or problem throughout the life of a modeling project.

B. Managing Peer Reviews

One means of quality control involves peer reviews of the models, their associated software, and their applications. One possible means of facilitating the peer review processes and for maintaining control on the particular versions of CALSIM II and accompanying models used for SWP-CVP planning and management decisions is another reason to create an interagency modeling consortium (IMC) consisting of DWR, USBR, and other stakeholder organization personnel if they are interested and want to participate. As suggested above, this consortium could be responsible for maintaining a toolbox of 'acceptable' peer-reviewed models for use by the agencies and contractors. The peer reviews should be of the theory underlying each

model, the model's software, the documentation of that software, the model's functions and capabilities including those pertaining to model data input and output, model calibration and verification, sensitivity analyses, uncertainty analyses, user control (GUIs), spatial and temporal resolutions, limiting assumptions, and on the model (as opposed to code) documentation.

Just having evidence of published articles about a particular model in peer reviewed journals is not a substitute for a peer review of the model software and its applicability or suitability for certain types of analyses for SWP-CVP. Peer reviews of all models, their software, and their use should be accomplished by experts both within and outside of the originating agencies. 'Inside' agency (or internal) reviews may uncover some needed changes and identify other issues or problems that external reviewers could be asked to specifically examine and address. Internal reviews can make the external review process more effective, less costly and less time consuming.

Peer reviews are considered a key process area for Level 3 and higher of the Capability Maturity Model guidelines for improving the software process (Carnegie Mellon University, 1994). The purpose of peer review evaluations is to find defects in the model formulation and software and in its use, i.e., model application. Peer reviewers can also identify possible ways of correcting those defects, if any. If there are no defects, or after all known defects have been corrected, both the developers and users of any model and its software can have a stronger basis for believing that their product and its output are reliable.

Peer reviews serve the same function as accountants. Once a firm's financial records have been peer reviewed by accountants (assuming they are qualified, objective and honest) the board of directors as well as the stockholders will have more assurance of the liabilities and net worth of their firm, and just how well it is being managed. In this case it is the assurance of the quality of the models, their software, and on their use in project evaluations, that actual and potential users of the model results depend upon.

The types of problems and issues for which a model, its software, and its documentation are designed to address are called the model's 'application niche'. Peer review of model development should include the evaluation of the intended application niche along with consideration of other aspects of model performance. Users of any model should be aware of the types of analyses for which the model is best suited and those for which the model is not well suited. This, along with the results of a peer review of any model application, should help the potential model user, or the user of the model results, better understand the limitations of the scientific basis of the model and just how much confidence can be placed on the model output.

Peer review triggers

Clearly judgment will have to be exercised as to just when and in what detail a peer review needs to be implemented. However the triggers on when a decision about a peer review needs to be made can be defined.

As shown in Figure 2, decisions regarding peer review are needed when models are proposed for the tool box and when model applications are completed. Should IMC decide a peer review is warranted when either of those events takes place, they will have to decide on the type of review and its level of detail. They will also need to identify the individuals to be asked to carry out that peer review.

Peer reviews are going to take time and cost money. They will also require IMC time to prepare the documentation needed for the peer reviewers and to read and act on reports prepared by the peer reviewers. This will apply if the peer review is internal or external.

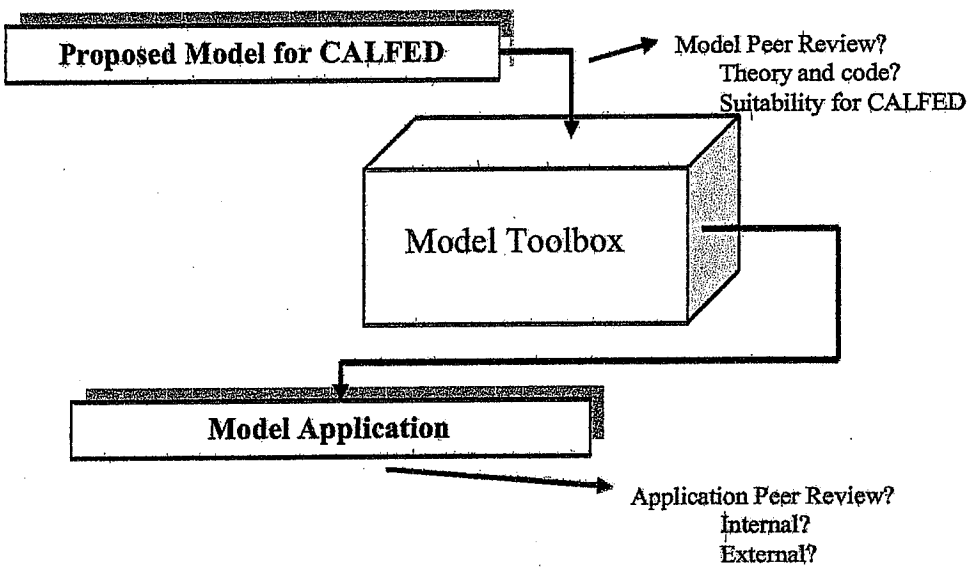

Figure 2. Schematic showing events where a peer review decision can be made.

The particular models and their associated software and documentation to be peer reviewed should be identified by the individuals or departments or agencies. This can include model process descriptions, software source code, documents, test results, and other supporting materials, as needed, for an adequate peer review of the entire model and its software. These products to be reviewed should be identified in writing and a written history of the review of different versions of each item should be maintained.

Events that take place in the progression of model development and use and subsequent modifications that warrant a peer review should be identified and specified in a written document. (This fits in to the model development and use documentation that should be maintained for Level 3 or higher CMM) When these events take place a peer review process should be considered, and if warranted, implemented. Depending on the event, the review can be solely internal, or it can involve an independent external review team as well.

Model application reviews should include an evaluation of the intended model application niche, and its applicability to current needs. Peer review may be appropriate for existing models when new information becomes available that could negate some or all of the conclusions of previous reviews or suggest a change in the currently specified application niche. Peer review of a model's applicability to a particular study should be planned well in advance of when model results are needed. The results of application reviews can influence the decisions made based on the model outputs. Once a peer review has been conducted for a particular model and its input data, peer reviews of subsequent applications of a model with similar inputs might be unnecessary. However, any time the model results may be controversial, or end up in litigation, another peer review may be justified.

Peer Review Process

The extent and process of performing and responding to peer reviews can vary in any organization. The ones discussed in this section attempt to follow the processes recommended by the Capability Maturity Model Level 3 guidelines.

Project peer review process should be specified in writing. A first step in this process should be to identify the particular modeling products and processes that will undergo peer review. This includes the models (i.e. the processes being modeled and the assumptions built into the models for describing these processes), their supporting software, the documentation of the model and its software, as well as all the written guidelines on how the models are to be used.

A second step is to perform an internal peer review prior to a model's use for project evaluation. It should be peer reviewed for accuracy, its suitability for use, and for identifying any possible errors in its logic, its coding, or in its documentation. Following an internal review, an external peer review can be performed.

Following the successful conclusion of internal and external peer reviews of a model and its documentation, the model can be applied to evaluate alternative projects. After the model has been applied to a particular project, the modeling process and its results should be peer reviewed to insure that the model has been applied properly, that the input data were appropriate, and that the conclusions drawn were valid.

Peer review teams should be selected, along with a peer review team leader. The particular personnel on the team will depend on the particular model and its software and documentation being reviewed. CALFED should have a list of qualified peer reviewers representing all applicable disciplines, both internal and external, that it can call upon to perform these reviews. The peer reviews are to be of the models and their use, not of the people who developed or used them. The reviews are to be used to evaluate the quality of modeling products and processes, not of the personnel involved.

Establishing and carrying out ongoing peer review processes costs money. Adequate funding must be made available to

1. identify and recruit a peer review team and team leader
2. prepare and distribute the peer review materials to the peer review team
3. support the time required for the team to review the materials prior to a team meeting
4. support the team meeting and to participate in it as appropriate (e.g., answering questions, conducting model experiments and sensitivity analyses, etc.)
5. reproduce and distribute the team report and to take actions as needed
6. monitor the modifications or changes being made to the model, its software, and its documentation, or redoing the model application, as needed.
7. prepare and distribute to model developers and potential users a report on the results of the peer review and the actions taken.

The particular peer review process may depend on just what is being peer reviewed and the resources and time available to perform the review. In general, however, the steps of a peer review could include the following:

1. DWR or CALFED should identify and establish a pool of possible reviewers representing various disciplines, with sufficient redundancy to allow for scheduling conflicts when ever some subset of those reviewers are needed. This includes both internal as well as external reviewers. What ever administrative work is need to establish this pool should be completed prior to when these reviewers will be needed.

2. At particular milestones in any new model development or in model application an internal peer review process could be initiated, to examine the modeling assumptions, the software that implements those assumptions in the case of model development or the data being used for model inputs in the case of model applications, and the documentation being prepared to describe the processes, to document the software code, and to document the tests that were run to test the code, or to document the results of the model application. If deemed appropriate, an external peer review could also be performed. If an external review is to take place, the particular reviewers need to be selected, notified, sent supporting documents, and be scheduled for one or more meetings, as needed. They should be issued contracts specifying the requirements (the checklist of items to be reviewed) and products expected.

3. Recommendations made by the peer review team need to be addressed and the actions taken along with the rationale for those actions should be documented.

4. The peer review team should review the actions taken and the results obtained from these actions. If not judged acceptable new recommendations should be made and submitted. A final report should be prepared by the peer review team when all recommendations have been successfully implemented or addressed, or if no further actions based on review team's recommendations will be taken by the model developers or users.

The time and effort required for various levels of review should also be assessed and provided to the review team so that they can carry out the level of review requested of them. Otherwise the reviews may be superficial and while appearing to be peer reviewed, a model and its

associated products may in fact be inadequately reviewed. Peer review teams have the responsibility to specify in writing the scope and limitations of their reviews.

As was the case for this peer review panel, the materials to be sent to the review team to allow them to prepare for their meeting should include the statement of review objectives and the level of detail desired, the applicable requirements and standards upon which to judge the adequacy of the products being reviewed, and of course the material that is to be reviewed. There should be a list of questions for the reviewers to address. Each review team member should be assigned and given responsibility for answering specific questions and for completing specific aspects of the overall review. All team members should be given specific review standards or requirements, including the expected completion dates. Checklists should be provided the review team that are applicable to the specific type of product being reviewed and the level of detail to be examined. These checklists will contain the criteria for judging the product, such as compliance with any standards and procedures, completeness, correctness, rules of construction, and maintainability.

Peer Review Issues and Questions

Each model development or application review will dictate its own special set of questions to be addressed. Some of these questions could relate to:

- Model Purpose and Objective
  - Use of model related to decisions being considered.
  - Model application niche, and why.
  - Model strengths and weaknesses –is it the best model?
- Model Processes and Limitations
  - Model processes, spatial and temporal scales, grid resolution.
  - Model variables and level of aggregation.
- Model Theoretical Basis
  - Model algorithms, numerical or analytical methods,
  - Model process formulation
  - Modeling approach in comparison with other models
  - Any shortcomings in relation to application niche
- Model Parameter Estimation
  - Methods used
  - Data available for parameter estimation
  - Parameter estimate reliabilities
  - Boundary conditions and appropriateness.
- Model Input Data Quantity/Quality
  - Data used in design of model
  - Data adequacy (quantity, quality, resolution) for model purpose and application
  - Data necessary for application of model
  - Key data gaps in model application
  - Additional data needs and why
- Model Key Assumptions
  - Basis for major assumptions

- Sensitivity of model outputs to key assumptions
- Sensitivity of potential decisions to key assumptions
- Ease in modifying key assumptions

- Model Performance Measures
  - Criteria for assessing model performance
  - Correspondence of model output with measured observed data
  - Any model bias throughout range of model predictions
  - Variability and uncertainty analyses and representations in model results
  - What determines model's variability and uncertainty.
  - Model performance relative to others in application niche
- Model Documentation and User's Guide
  - Clarity of documentation, comprehensiveness of user's guide
  - Model applicability and limitations
  - Input data requirements for calibration, verification, model runs
  - Post modeling analyses, display and interpretation of results
  - Model code documentation
  - Model application documentation examples for prospective users.
- Review Retrospective
  - How well model and its application meet objectives and needs of project
  - Possible changes in the model to improve model performance
  - Robustness of model solutions to small changes in uncertain parameters, etc.
  - Ease of including uncertainty analyses associated with uncertain input data.
  - Key research needs for model improvement.

Peer Review Completion Reports

Procedures need to be established to track and confirm actions based on suggested changes or modifications in the material being reviewed. Once these actions are taken and completed, and documented, the peer review process for that particular product is completed. Peer review completion reports should contain data on what was reviewed and the results of the review. These data should include a description of the products that were reviewed, the level of detail of the review, any review limitations or qualifications, the number and backgrounds of the reviewers, the time spent preparing for and during review team meetings, the defects found and recommendations made, and the actions taken to address these recommendations.

Overall Peer Review Evaluations

The IMC or initiating agency should document the planning for and scheduling of peer reviews. The products to be reviewed and the level of detail to be examined also need to be specified. The procedures to be followed for selecting peer review team members, and the team leader, should also be determined and documented. Procedures for training potential reviewers, if such training is needed, should be identified and implemented, as required.

Periodically the IMC or applicable agency should assess just how well the plan described in the preceding paragraph is being carried out, and just how beneficial these peer reviews are to the overall modeling effort. Measures should be identified and used to determine the status of the

peer review activities. These measures could include the number of completed peer reviews performed compared to the number expected to be performed, the overall effort expended on peer reviews compared to that expected, and the number and extent of peer review recommendations requiring actions.

At a minimum these periodic reviews should verify that

1. The planned peer reviews and/or audits are conducted.
2. The peer review leaders are adequately trained for their roles.
3. The reviewers are properly trained or experienced in their roles.
4. The processes for preparing for and conducting peer reviews, and for following up on reviewer's recommendations are adequate and are being followed.
5. The reporting of peer review results is complete, accurate, timely and is being made available to model users.

Risk Management Template

Risk Definition Name	Enter a short name that uniquely defines the risk
Risk #	Enter a unique number assigned to the risk. Range starts with 1 and continues.
Date Risk Identified	Enter the date the risk was identified
Risk Identification Source	Enter the source of the risk identification. In example, meeting name, group, or person.
Risk Owner	Enter the name of the person who will be responsible for ensuring the risk is approved, managed, periodically assessed, communicated, and tracked through closed or transfer.
Risk Detailed Description	Enter a detailed description of the risk so that a reader clearly understands the risk.
Probable Impact of Risk on Project (H, M, L)	Enter the impact on the project. o High = the risk will most likely occur and the impact could prevent the project from achieving its purpose. o Medium = there is a 50/50 change the risk would occur and the impact is serious but the project could still achieve its purpose if appropriately managed. o Low = there is a low probability that the risk would occur and minimal impact to the project's purpose.
Probable Impact of Risk on Project Costs	Enter the impact on the project in dollars. Determine what the potential cost to the project would be if the risk occurs.
Probable Impact of Risk on Project Schedule	Enter the schedule impact on the project. Determine how the schedule would be potentially impacted if the risk occurs.
Probable Impact of Risk on Project Results	Enter the impact on the project. Determine how the overall project purpose and results will be potentially impacted if the risk occurs.
Detailed Plan to Mitigate or Transfer Risk	Enter the detailed plan to mitigate the risk or a statement that the risk will be accepted. Mitigation could include ways to minimize, avoid, or transfer the risk to another party or group. Risk transfer would include evidence of agreement by the accepting party.
Detailed Project Action Items Required to Mitigate or Transfer Risk	Enter the detailed action items required to mitigate the risk. These items will be summarized and assigned within the project Action Log, along with an action item owner, and target completion date.
Detailed Project Plan Tasks Required to Mitigate Risk	Enter the detailed project plan task required to mitigate the risk. These items will be summarized and contained within the MS Project Schedule along with the effort, duration, schedule, and assigned resources.
Comments	Enter any permanent comments that cannot be included in the above items.
Referenced Documents	Enter any documents that a reader should consider in understanding, analyzing, mitigating, or accepting this risk.
Date Risk Closed	Enter the date this risk was closed. This would include when all action items or project tasks were completed, or the risk was transferred to another party or group.

Appendix F: Analysis of the November 2003 CALSIM II Validation Report

The following comments come from an analysis of the model results presented in the validation report *'CALSIM II Simulation of Historical SWP/CVP Operations'*, DWR (2003). The observations relate to the formulation of the model at November 2003. Changes might be made to that formulation which could resolve these issues.

Overestimation of Project Deliveries

The validation run suggests that the modeled demands included in CALSIM II overestimate the actual demands. CVP demands south of the Delta are assumed to be always equal to the contract entitlement whereas the observed deliveries in unrestricted years are consistently less than this amount. The modeled North of Delta deliveries are also consistently higher than observed. The modeled and observed CVP deliveries from the validation report are listed in Table 1.

Table 1. Comparison of modelled and observed CVP deliveries (1975-1998)

Project	Simulated Delivery (Taf/yr)	Historical Delivery (taf/yr)	Difference (taf/yr)	% Difference
CVP North of Delta	1960	1750	210	12
CVP South of Delta	2650	2490	160	6.4

Because the SWP south of delta demands were set to historical deliveries in many years, comparison with the historical deliveries in the validation report is of limited validity. However the fact that the historical SWP deliveries over the last ten years have averaged only 2385 taf/year while the modeled 'year 2001 development' SWP Delta deliveries reported in the 2002 State Water Project Delivery Reliability Report average 3090 taf/year, suggests that modeled SWP deliveries may also be too high.

Allocations to Project Contractors

Seasonal allocations to SWP and CVP contractors are made on the basis of water in storage, forecast inflows, projected carryover storage requirements and in-Basin and Delta regulatory requirements. The allocation processes used by the operators and those used by CALSIM II, are not identical. An examination of the way that CALSIM II has restricted project deliveries during the dry period of 1987-1992 (Figures 10, 16, 17 and 24 of the validation report) suggests that CALSIM II has allocated less water in the early years of the dry sequence than occurred in practice and consequently had more water available in 1991 and 1992 when the most severe restrictions were experienced. The carryover storage rules adopted can have a significant impact on the expected frequency and severity of water supply restrictions. The

model rules need to be examined to ensure that the accurately reflect the way the system will be managed in the future.

San Luis Reservoir Operation

The rules used by the system operators for transferring water from headwater storages to the San Luis Reservoir can have a significant impact on:

- the pattern of flow in the Delta,
- the operation of accounting rules between the SWP and the CVP and
- opportunities for SWP wheeling of CVP water and possibly the availability of Article 21 water to SWP contractors.

A comparison of the modeled and observed storage behavior of the SWP component of San Luis (Figure 15) reveals that the model consistently underestimates the volume in storage. A comparison of the CVP component of the storage (Figure 23) indicates that the actual storage is filled earlier in the season and that the actual storage is also slightly higher than the modeled.

Users of CALSIM II output need to be confident that the rules adopted by the model for determining these transfers reflect the way this component of the system will be operated in the future.

Appendix G: Some Principles for Strategic Water Analysis for the California Water Plan Bulletin 160-03 (from the stakeholder review Draft, Sept. 30, 2003)

Strategy:

1) A frequently amended strategic document will lay out DWR's strategic analysis framework and identify the technical objectives, roles, and responsibilities of major DWR data collection efforts and analytical tools and their interactions and their responsible managers.

Transparency:

2) All data and models should be in the public domain and available on the web.
3) All data and models should have significant documentation.
4) Known limitations should be documented.

Longer-term viability:

5) Modularity: Major analytical tools will be designed and implemented to fit modularly and explicitly within the larger strategic analysis framework.
6) Adaptive data management framework: Major data efforts will fall within a larger data management framework, including protocols for data documentation and updating, and documentation of limitations.
7) A frequently-updated document will outline short-term and long-term efforts, budgets, and responsibilities for continuous improvement of analytical tools and data, with policy for continued user, local agency, and stakeholder involvement.

Coverage:

8) Spatial coverage for the basic data and analytical framework will be statewide.
9) Local and regional water management and resources will be explicitly represented.

Accountability and Quality Control:

10) In developing analytical tools, systematic efforts should be made to involve local agencies and stakeholders.
11) Major analytical products will undergo external review by a) external unaffiliated experts and b) local agencies whose systems are included in the model. User groups will exist for all major analytical products.
12) DWR's strategic analysis framework will undergo periodic internal and external review.

Appendix H: Model Sensitivity and Uncertainty Analysis

(This is a draft of a book chapter by DPL/JRS that may be useful for CALSIM II developers)

1. Introduction

2. Issues, concerns, and terminology

3. Variability and uncertainty in model output
- **3.1 Natural variability**
- **3.2 Knowledge uncertainty**
- **3.3 Decision uncertainty**

4. Sensitivity and uncertainty analyses
- **4.1 Sensitivity Analyses**
- **4.2 Uncertainty Analyses**

5. Performance indicator uncertainties
- **5.1 Performance measure target uncertainty**
- **5.2 Distinguishing differences between performance indicator distributions**

6. Communicating model output uncertainty

7. Conclusions

8. References

The usefulness of any model is in part dependent on the accuracy and reliability of its output data. Yet, because all models are imperfect abstractions of reality, and because precise input data are rarely if ever available, all output values are subject to imprecision. The input data and modeling uncertainties are not independent of each other. They can interact in various ways. The end result is imprecision and uncertainty associated with model output. This chapter focuses on ways of identifying, quantifying, and communicating the uncertainties in model outputs.

1. Introduction

Models are the primary way we have to estimate the multiple affects of alternative water resource system design and operating policies. Models predict the values of various system performance indicators. Model outputs are based on model structure, hydrologic and other time-series inputs and a host of parameters whose values describe the system being simulated. Even if these assumptions and input data reflect, or are at least representative of, conditions believed to be true, we know they will be wrong. Our models are always simplifications of the

real systems we are studying. Furthermore, we simply cannot forecast the future with precision. So we know the model outputs of future conditions are uncertain estimates, at best.

Some prediction uncertainties can be reduced by additional research and data collection and analysis. Before undertaking expensive studies to gather and analyze additional data it is reasonable to ask what improvement in estimates of system performance or what reduction in the uncertainty associated with those estimates would result if all data and model uncertainties could be reduced. Such information helps determine how much one would be willing to 'pay' to reduce prediction uncertainty. If prediction uncertainty on average is costing a lot, it may pay to invest in additional data collection, more studies, or in better models all aimed at reducing that prediction uncertainty. If that uncertainty has no, or only a very modest, impact on the likely decision that is to be made, one should find other issues to worry about.

If it appears that reducing prediction uncertainty is worthwhile, then one should consider how best to do it. If doing this involves obtaining additional information, then it is clear that the value of this additional information, however measured, should exceed the cost of obtaining it. The value of such information will be the increase in system performance, or the reduction in its variance, that one can expect from obtaining such information. If additional information is to be obtained, it should be that information which reduces the uncertainties considered important, not the unimportant ones.

This chapter reviews some methods for identifying and communicating model prediction uncertainty. The discussion begins with a review of the causes of risk and uncertainty in model output. It then examines ways of measuring or quantifying uncertainty and model output sensitivity to model input imprecision, concentrating on methods that seem most relevant or practical for large-scale regional simulation modeling. It builds on some of the statistical methods reviewed in Chapter III and the modeling of risk and uncertainty in Chapter VI.

2. Issues, concerns, and terminology

Outcomes or events that cannot be predicted with certainty are often called risky or uncertain. Some individuals draw a special and interesting distinction between risk and uncertainty. In particular, the term risk is often reserved to describe situations for which probabilities are available to describe the likelihood of various events or outcomes. If probabilities of various events or outcomes cannot be quantified, or if the events themselves are unpredictable, some would say the problem is then one of uncertainty, and not of risk. In this chapter what is not certain is considered uncertain, and uncertainty is often described by a probability distribution. When the ranges of possible events are known and their probabilities are measurable, risk is called objective risk. If the probabilities are based solely on human judgment, the risk is called subjective risk.

Such distinctions between objective and subjective risk, and between risk and uncertainty, rarely serve any useful purpose to those developing and using models. Likewise the distinctions are often unimportant to those who should be aware of the risks or uncertainties associated with system performance indicator values.

Uncertainty in information is inherent in future-oriented planning efforts. Uncertainty stems from inadequate information and incorrect assumptions, as well as from the variability of natural processes. Water managers often need to identify both the uncertainty as well as the sensitivity of, or changes in, system performance indicator values due to the any changes in possible input data and parameter values from what were predicted. They need to reduce this level of uncertainty to the extent practicable. Finally, they need to communicate the residual uncertainties clearly so that decisions can be made with this knowledge and understanding.

Sensitivity analysis can be distinguished from uncertainty analysis. Sensitivity analysis procedures explore and quantify the impact of possible errors in input data on predicted model outputs and system performance indices. Simple sensitivity analysis procedures can be used to illustrate either graphically or numerically the consequences of alternative assumptions about the future. Uncertainty analyses employing probabilistic descriptions of model inputs can be used to derive probability distributions of model outputs and system performance indices. Figure 1 illustrates the impact of both input data sensitivity and input data uncertainty on model output uncertainty.

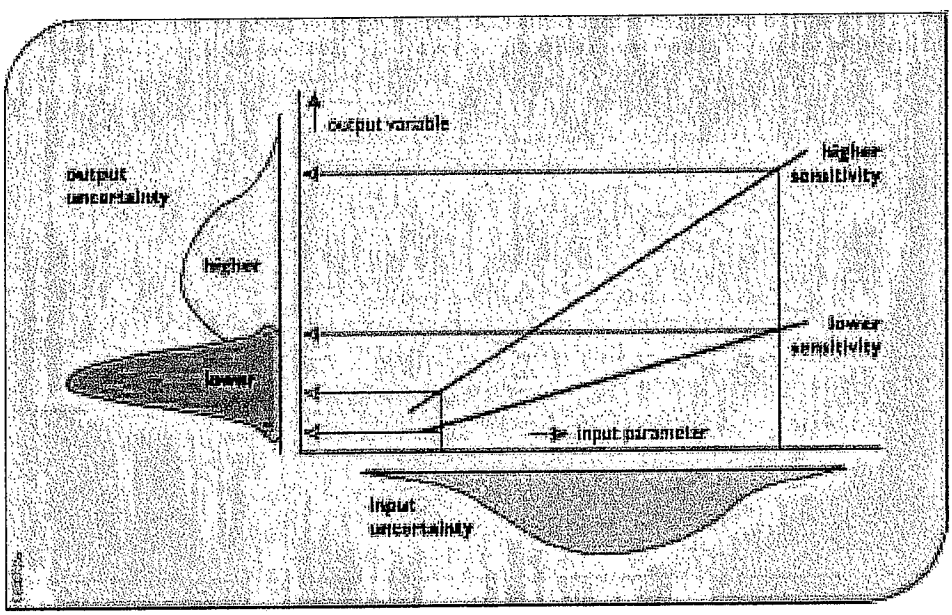

Figure 1. Schematic diagram showing relationship among model input parameter uncertainty and sensitivity to model output variable uncertainty (Lal, 1995).

It is worthwhile to explore the transformation of uncertainties in model inputs and parameters into uncertainty in model outputs when conditions differ from those reflected by the model inputs. Historical records of system characteristics are typically used as a basis for model inputs. Yet conditions in the future may change. There may be changes in the frequency and

amounts of precipitation, changes in land cover and topography, and changes in the design and operation of control structures, all resulting in changes of water stages and flows, and their qualities, and consequently changes in the impacted ecosystems.

If asked how the system would operate with inputs similar to those in the historical database, the model should be able to interpolate within the available knowledge base to provide a fairly precise estimate. Still that estimate will not be perfect. This is because our ability to reproduce current and recent operations is not perfect, though it should be fairly good. If asked to predict system performance for situations very different from those in the historical knowledge base, or when the historical data are not considered representative of what might happen in the future, say due to climate change, such predictions become much less precise. There are two reasons why. First, our description of the characteristics of those different situations or conditions may be imprecise. Second, our knowledge base may not be sufficient for calibrating model parameters in ways that would enable us to reliably predict how the system will operate under conditions unlike those that have been experienced historically. The more conditions of interest are unlike those in the historical knowledge base, the less confidence we have that the model is providing a reliable description of systems operation. Figure 2 illustrates this issue.

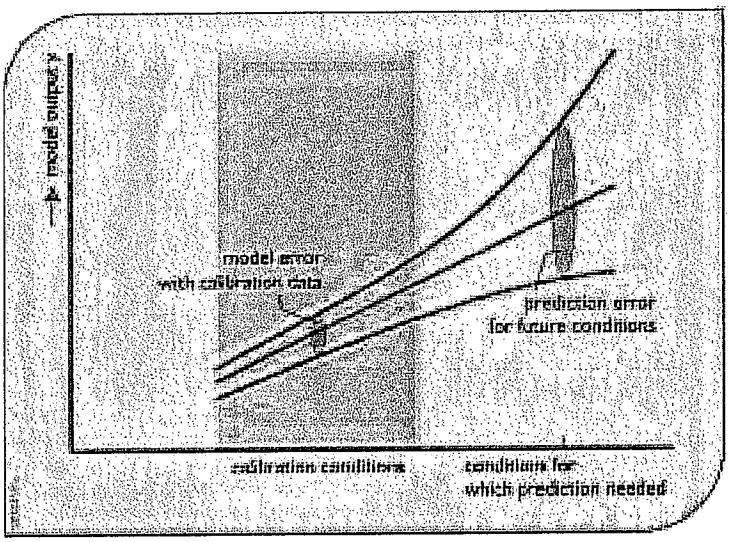

Figure 2. The precision of model predictions is affected by the difference between the conditions or scenarios of interest and the conditions or scenarios for which the model was calibrated.

Clearly a sensitivity analysis needs to consider how well a model can replicate current operations, and how similar the target conditions or scenarios are to those described in the

historical record. The greater the required extrapolation from what has been observed, the greater will be the importance of parameter and model uncertainties.

The relative and absolute importance of different parameters will depend on the system performance indicators of interest. Seepage rates may have a very large local effect, but a small global effect. Changes in system-wide evapotranspiration rates will likely impact system-wide flows. The precision of model projections and the relative importance of errors in different parameters will depend upon the:

(1) precision with which the model can reproduce observed conditions,
(2) difference between the conditions predicted and the historical experience included in the knowledge base, and the
(3) system performance characteristics of interest.

Errors and approximations in input data measurement, parameter values, model structure and model solution algorithms, are all sources of uncertainty. While there are reasonable ways of quantifying and reducing these errors and the resulting range of uncertainty of various system performance indicator values they are impossible to eliminate. Decisions will still have to be made in the face of a risky and uncertain future. Decisions can be modified as new data and knowledge are obtained in a process of adaptive management.

There is also uncertainty with respect to human behavior and reaction related to particular outcomes and their likelihoods, i.e., to their risks and uncertainties. As important as risks and uncertainties associated with human reactions are to particular outcomes, they are not usually part of the models themselves. Social uncertainty may often be the most significant component of the total uncertainty associated with just how a water resource system will perform. For this reason we should seek designs and operating policies that are flexible and adaptable.

When uncertainties associated with system operation under a new operating regime are large, one should anticipate the need to make changes and improvements as experience is gained and new information accumulates. When predictions are highly unreliable, responsible managers should favor actions that are robust (e.g., good under a wide range of situations), gain information through research and experimentation, monitor results to provide feedback for the next decision, update assessments and modify policies in the light of new information, and avoid irreversible actions and commitments.

3. Variability and uncertainty in model output

Differences between model output and observed values can result from either natural variability, say caused by unpredictable rainfall, evapotranspiration, water consumption, and the like, and/or by both known and unknown errors in the input data, the model parameters, or the model itself. The later is sometimes called knowledge uncertainty but it isn't always due to a lack of knowledge. Models are always simplifications of reality and hence 'imprecision' can result. Sometimes imprecision occurs because of a lack of knowledge, such as just how a

particular species will react to various environmental and other habitat conditions. Other times known errors are introduced simply for practical reasons.

Imperfect representation of processes in a model constitutes model structural uncertainty. Imperfect knowledge of the values of parameters associated with these processes constitutes model parameter uncertainty. Natural variability includes both temporal variability and spatial variability, to which model input values may be subject.

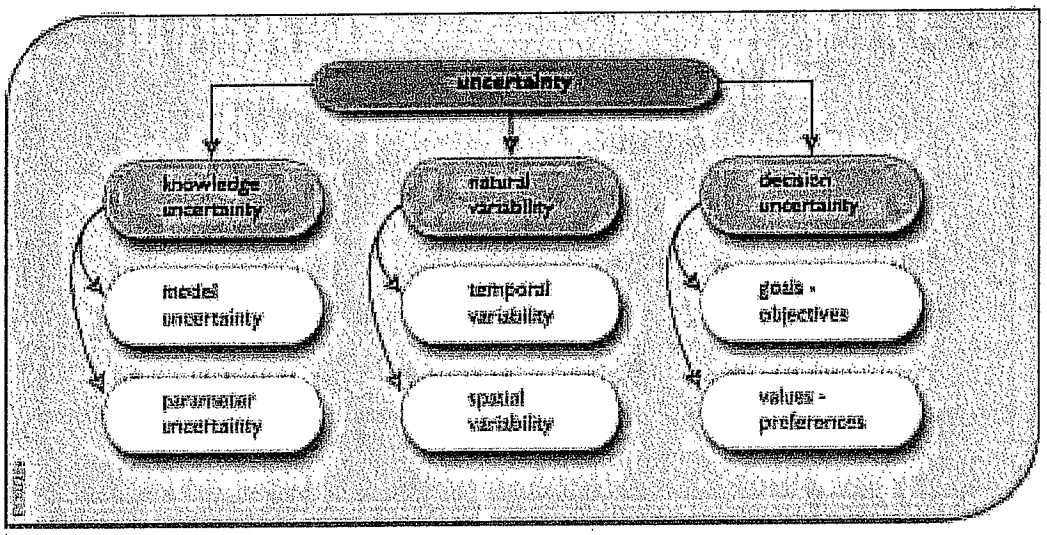

Figure 3. One way of classifying types of uncertainty.

Figure 3 illustrates these different types of uncertainty. For example, the rainfall measured at a weather station within a particular model grid cell may be used as an input value for that cell, but the rainfall may actually vary at different points within that cell and its mean value will vary across the landscape. Knowledge uncertainty can be reduced through further measurement and/or research. Natural variability is a property of the natural system, and is usually not reducible at the scale being used. Decision uncertainty is simply an acknowledgement that we cannot predict ahead of time just what decisions individuals and organizations will make, or even just what particular set of goals or objectives will be considered and the relative importance of each.

Rather than contrasting 'knowledge' uncertainty vs. natural variability vs. decision uncertainty, one can classify uncertainty in another way based on specific sources of uncertainty, such as those listed below, and address ways of identifying and dealing with each source of uncertainty.

Informational Uncertainties:

- imprecision in specifying the boundary and initial conditions that impact the output variable values
- imprecision in measuring observed output variable values

Model Uncertainties:

- uncertain model structure and parameter values
- variability of observed input and output values over a region smaller than the spatial scale of the model
- variability of observed model input and output values within a time smaller than the temporal scale of the model. (e.g., rainfall and depths and flows within a day)
- errors in linking models of different spatial and temporal scales

Numerical Errors:

- errors in the model solution algorithm

3.1 Natural variability

The main source of hydrologic model output value variability is the natural variability in hydrological and meteorological input series. Periods of normal precipitation and temperature can be interrupted by periods of extended drought and intense meteorological events such as hurricanes and tornadoes. There is no reason to think such events will not continue to occur and become even more frequent and extreme. Research has demonstrated that climate has been variable in the past and concerns about anthropogenic activities that may increase that variability increase each year. Sensitivity analysis can help assess the affect of errors in predictions if those predictions are based only on past records of historical time-series data describing precipitation, temperature and other exogenous forces across and on the border of the regions being studied.

Time series input data are often actual, or at least based on, historical data. The time-series values typically describe historical conditions including droughts and wet periods. What is distinctive about natural uncertainty, as opposed to errors and uncertainty due to modeling limitations, is that natural variability in meteorological forces cannot be reduced by improving the model's structure, increasing the resolution of the simulation, or by better calibration of model parameters.

Errors result if meteorological values are not measured or recorded accurately, or if mistakes are made in the generation of computer data files. Furthermore, there is no assurance the statistical properties of historical data will accurately represent the statistical properties of future data. Actual future precipitation and temperature scenarios will be different from those in the past, and this difference in many cases may have a larger affect than the uncertainty due to incorrect parameter values. However, the affects of uncertainties in the parameter values

used in stochastic generation models are often much more significant than the affects of using different stochastic generation models (Stedinger and Taylor, 1982).

While variability of model output is a direct result of variability of model input (e.g., hydrologic and meteorological data), the extent of the variability, and the lower and upper limits of that variability, may also be affected by errors in the inputs, the values of parameters, initial boundary conditions, model structure, processes and solution algorithms.

Figure 4 illustrates the distinction between the variability of a system performance indicator due to input data variability, and the extended range of variability due to the total uncertainty associated with any combination of the causes listed in the previous section. This extended range is what is of interest to water resource planners and managers.

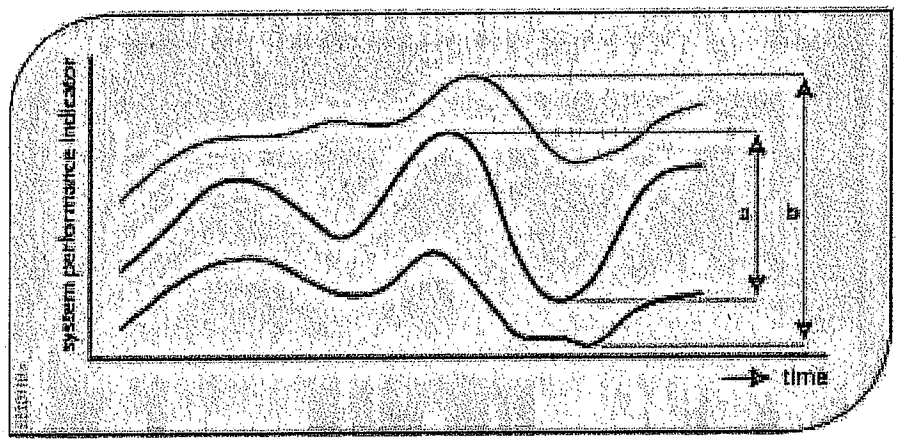

Figure 4. Time-series of model output or system performance showing variability over time. Range "a" results from the natural variability of input data over time. The extended range "b" results from the variability of natural input data as well as from imprecision in input data measurement, parameter value estimation, model structure and errors in model solution algorithms. The extent of this range will depend on the confidence level associated with that range.

What can occur in practice is a time-series of system performance indicator values that can range anywhere within or even outside the extended range, assuming the confidence level of that extended range is less than 100%. The confidence one can have that some future value of a time series will be within a given range is dependent on two factors. The first is the number of measurements used to compute the confidence limits. The second is on the assumption that those measurements are representative of - come from the same statistical or stochastic process yielding - future measurements. Figure 5 illustrates this point. Note that the time series may even contain values outside the range "b" defined in Figure 4 if the confidence level of that range is less than 100%. Confidence intervals associated with less than 100% certainty will not include every possible value that might occur.

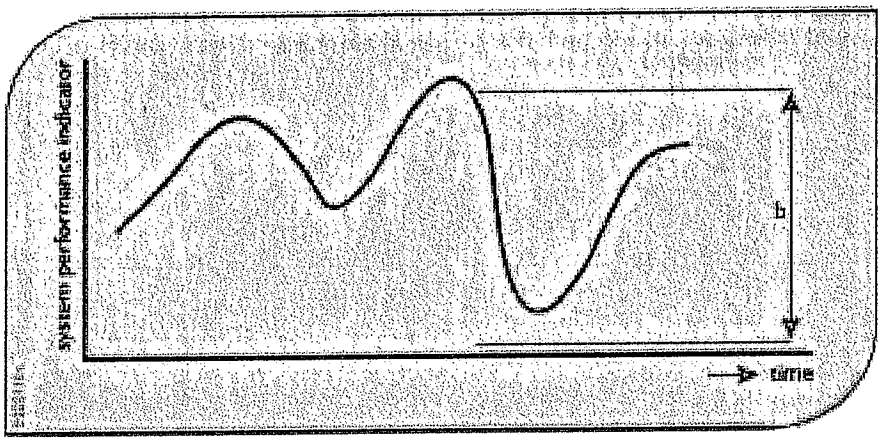

Figure 5. Typical time series of model output or system performance indicator values that are the result of input data variability and possible imprecision in input data measurement, parameter value estimation, model structure and errors in model solution algorithms.

3.2 Knowledge uncertainty

Referring to Figure 3, knowledge uncertainty includes model structure and parameter value uncertainties. First we consider parameter value uncertainty including boundary condition uncertainty, and then model and solution algorithm uncertainty.

3.2.1 Parameter value uncertainty

A possible source of uncertainty in model output results from uncertain estimates of various model parameter values. If the model calibration procedure were repeated using different data sets, different parameter values would result. Those values would yield different simulated system behavior, and thus different predictions. We can call this parameter uncertainty in the predictions because it is caused by imprecise parameter values. If such parameter value imprecision were eliminated, then the prediction would always be the same and so the parameter value uncertainty in the predictions would be zero. But this does not mean that predictions would be perfectly accurate.

In addition to parameter value imprecision, uncertainty in model output can result from imprecise specification of boundary conditions. These boundary conditions can be either fixed or variable. However, because they are not being computed based on the state of the system, their values can be uncertain. These uncertainties can affect the model output, especially in the vicinity of the boundary, in each time step of the simulation.

3.2.2 Model structural and computational errors

Uncertainty in model output can also result from errors in the model structure compared to the real system, and approximations made by numerical methods employed in the simulation. No matter how good our parameter value estimates, our models are not perfect and there is a residual model error. Increasing model complexity to more closely represent the complexity of the real system may not only add to the cost of data collection, but also introduce even more parameters, and thus even more potential sources of error in model output. It is not an easy task to judge the appropriate level of model complexity, and to estimate the resulting levels of uncertainty associated with various assumptions regarding model structure and solution methods. Kuczera (1988) provides an example of a conceptual hydrologic modeling exercise with daily time steps where model uncertainty dominated parameter value uncertainty.

3.3 Decision uncertainty

Uncertainty in model predictions can result from unanticipated changes in what is being modeled. These can include changes in nature, human goals, interests, activities, demands, and impacts. An example of this is the deviation from standard or published operating policies by operators of infrastructure such as canal gates, pumps, and reservoirs in the field, as compared to what is specified in documents and incorporated into the water systems models. Comparing field data with model data for model calibration may yield incorrect calibrations if operating policies actually implemented in the field differ significantly from those built into the models. What do operators do in times of stress? And can anyone identify a place where deviations from published policies do not occur?

What humans will want to achieve in the future may not be the same as what they want today. Predictions of what people will want in the future are clearly sources of uncertainty. A perfect example of this is in the very flat Greater Everglades region of south Florida in the US. Fifty years ago folks wanted the swampy region protected from floods and drained for agricultural and urban development. Today many want just the opposite at least where there are no human settlements. They want to return to a more natural hydrologic system with more wetlands and unobstructed flows, but now for ecological restoration objectives that were not a major concern or much appreciated some half a century ago. Once the mosquitoes return and if the sea level continues to rise, future populations who live there may want more flood control and drainage again. Who knows? Complex changing social and economic processes influence human activities and their demands for water resources and environmental amenities over time. Some of these processes reflect changes in local concerns, interests and activities, but population migration and many economic activities and social attitudes can also reflect changing national and international trends.

Sensitivity scenarios that include human activities can help define the affects of those activities within an area. It is important that careful attention go into the development of these alternative scenarios so that they realistically capture the forces or stresses that the system may face. The history of systems studies are full of examples where the issues studied were rapidly

overwhelmed by much larger social forces resulting from, for example, the relocation of major economic activities, an oil embargo, changes in national demand for natural resources, economic recession, sea-level rise, an act of terrorism, or even war. One thing is sure; the future will be different than the past, and no one is certain just how.

3.3.1 Surprises

Water resource managers may also want to consider how vulnerable a system is to undesirable environmental surprises. What havoc might an introduced species like the zebra mussel invading the Great Lakes of North America have in a particular watershed? Might some introduced disease suddenly threaten key plant or animal species? Might management plans have to be restructured to address the survival of some species such as salmon in the Rhine River in Europe or in the Columbia River in North America? Such uncertainties are hard to anticipate when by their nature they are truly surprises. But surprises should be expected. Hence system flexibility and adaptability should be sought to deal with changing management demands, objectives, and constraints.

4. Sensitivity and uncertainty analyses

An uncertainty analysis is not the same as a sensitivity analysis. An uncertainty analysis attempts to describe the entire set of possible outcomes, together with their associated probabilities of occurrence. A sensitivity analysis attempts to determine the relative change in model output values given modest changes in model input values. A sensitivity analysis thus measures the change in the model output in a localized region of the space of inputs. However, one can often use the same set of model runs for both uncertainty analyses and sensitivity analyses. It is possible to carry out a sensitivity analysis of the model around a current solution and then use it as part of a first order uncertainty analysis.

This discussion begins by focusing on some methods of uncertainty analysis. Then various ways of performing and displaying sensitivity analyses are reviewed.

4.1 Uncertainty Analyses

Recall that uncertainty involves the notion of randomness. If a value of a performance indicator or performance measure, or in fact any variable, like the phosphorus concentration or the depth of water at a particular location varies and this variation over space and time cannot be predicted with certainty, it is called a random variable. One cannot say with certainty what the value of a random variable will be but only the likelihood or probability that it will be within some specified range of values. The probabilities of observing particular ranges of values of a random variable are described or defined by a probability distribution. There are many types of distributions and each can be expressed in several ways as presented in Chapter III.

Suppose the random variable is X. If the observed values of this random variable can be only discrete values, the probability distribution of X can be expressed as a histogram, as shown in Figure 6a. The sum of the probabilities for all possible outcomes must equal 1. If the random variable is a continuous variable that can assume any real value over a range of values, the probability distribution of X can be expressed as a continuous distribution as shown in Figure 6b. The shaded area under the density function for the continuous distribution is 1. The area between two values of the continuous random variable, such as between u and v in Figure 6c, represents the probability that the observed value x of the random variable value X will be within that range of values.

The probability distribution, $P_X(x)$ shown in Figure 6 (a) is called a probability mass function. The probability distributions shown in Figure 6 (b and c) are called a probability density functions (pdf) and are denoted by $f_X(x)$. The subscript X of P_X and f_X represents the random variable, and the variable x is some value of that random variable X.

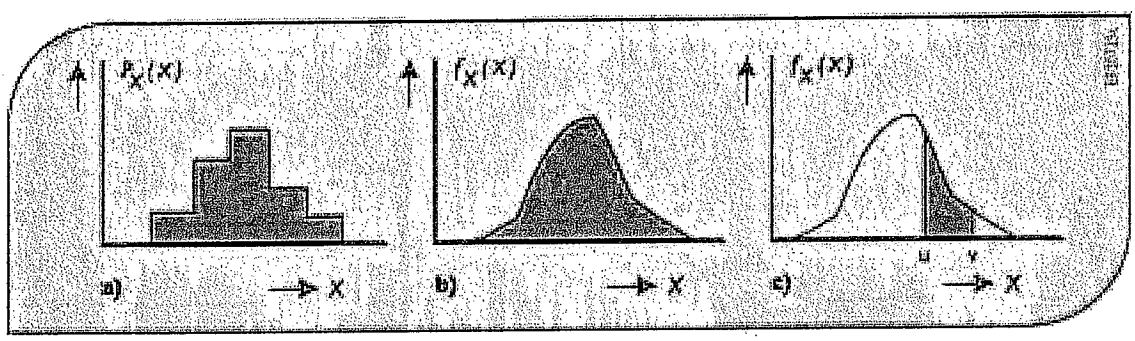

Figure 6. Probability distributions for a discrete or continuous random variable X. The area under the distributions (shaded areas in a and b) is 1, and the shaded area in c is the probability that the observed value x of the random variable X will be between u and v.

Uncertainty analyses involve identifying characteristics of various probability distributions of model input and output variables, and subsequently functions of those random output variables that are performance indicators or measures. Often targets associated with these indicators or measures are themselves uncertain.

A complete uncertainty analysis would involve a comprehensive identification of all sources of uncertainty that contribute to the joint probability distributions of each input or output variable. Assume such analyses were performed for two alternative project plans, A and B, and that the resulting probability density distributions for a specified performance measure were as shown in Figure 7. Figure 7 also identifies the costs of these two projects. The introduction of two performance criteria, cost and probability of exceeding a performance measure target (e.g., a pollutant concentration standard) introduces a conflict where a tradeoff must be made.

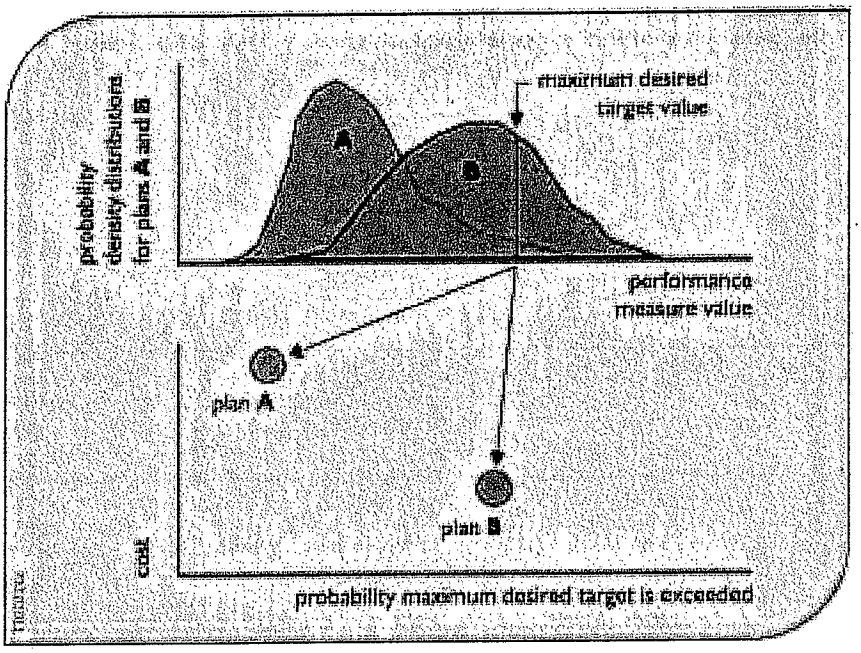

Figure 7. Tradeoffs involving cost and the probability that a maximum desired target value will be exceeded. In this illustration we want the lowest cost (*B* is best) and the lowest probability of exceedance (*A* is best).

4.1.1 Model and model parameter uncertainties

Consider a situation as shown in Figure 8, in which for a specific set of model inputs, the model outputs differ from the observed values, and for those model inputs, the observed values are always the same. Here nothing randomly occurs. The model parameter values or model structure needs to be changed. This is typically done in a model calibration process.

Given specific inputs, the outputs of deterministic models are always going to be the same each time those inputs are simulated. If for specified inputs to any simulation model the predicted output does not agree with the observed value, as shown in Figure 8, this could result from imprecision in the measurement of observed data. It could also result from imprecision in the model parameter values, the model structure, or the algorithm used to solve the model.

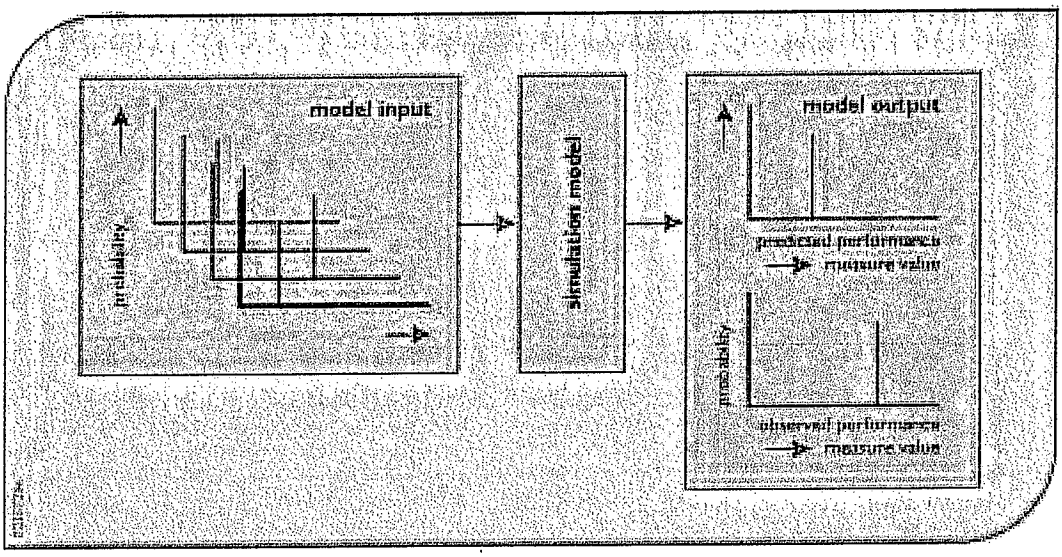

Figure 8. A deterministic system and a simulation model of that system needing calibration or modification in its structure. There is no randomness, only parameter value or model structure errors to be identified and corrected.

Next consider the same deterministic simulation model but now assume at least some of the inputs are random, i.e., not predictable, as may be case when random outputs of one model are used as inputs into another model. Random inputs will yield random outputs. The model input and output values can be described by probability distributions. If the uncertainty in the output is due only to the uncertainty in the input, the situation is similar to that shown in Figure 8. If the distribution of performance measure output values does not fit or is not identical to the distribution of observed performance measure values, then calibration of model parameter values or modification of model structure may be needed.

If a model calibration or 'identification' exercise finds the 'best' values of the parameters to be outside reasonable ranges of values based on scientific knowledge, then the model structure or algorithm might be in error. Assuming the algorithms used to solve the models are correct and observed measurements of system performance vary for the same model inputs, as shown in Figure 9, it can be assumed that the model structure does not capture all the processes that are taking place that impact the value of the performance measures. This is often the case when relatively simple and low-resolution models are used to estimate the hydrological and ecological impacts of water and land management policies. However, even large and complex models can fail to include or adequately describe important phenomena.

In the presence of informational uncertainties there may be considerable uncertainty about the values of the "best" parameters during calibration. This problem becomes even more pronounced with increases in model complexity.

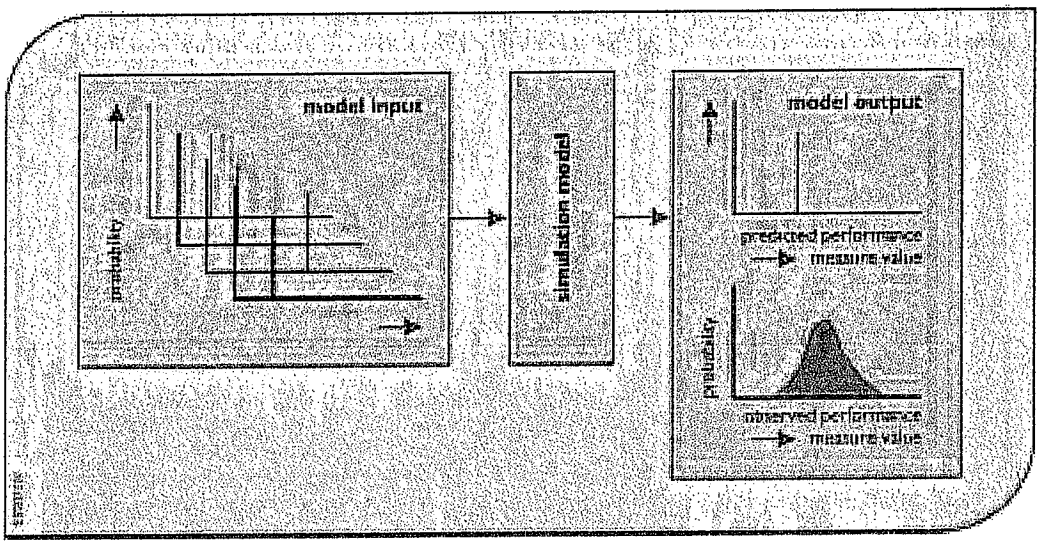

Figure A deterministic simulation model of a 'random or stochastic' system. To produce the variability in the model output that is observed in the real system, even given the same input values, the model's parameter values may need to vary over distributions of values and/or the model structure may need modification along with additional model inputs.

An example: Consider the prediction of a pollutant concentration at some site downstream of a pollutant discharge site. Given a streamflow Q (in units of 1000 m^3/day), the distance between the discharge site and the monitoring site, X (m), the pollutant decay rate constant k (day^{-1}), and the pollutant discharge W (Kg/day), we can use the following simplified model to predict the concentration of the pollutant C (g/m^3 = mg/l) at the downstream monitoring site:

$$C = (W/Q)\exp\{-k(X/U)\}$$

In the above equation assume the velocity U (m/day) is a known function of the streamflow Q.

In this case the observed value of the pollutant concentration C may differ from the computed value of C even for the same inputs of W, Q, k, X, and U. Furthermore, this difference varies in different time periods. This apparent variability, as illustrated in Figure 9, can be simulated using the same model but by assuming a distribution of values for the decay rate constant k. Alternatively the model structure can be modified to include the impact of streamflow temperature T on the prediction of C.

$$C = (W/Q)\exp\{-k\theta^{T-2}(X/U)\}$$

Now there are two model parameters, the decay rate constant k and the dimensionless temperature correction factor θ and an additional model input, the streamflow temperature, T. It could be that the variation in streamflow temperature was the sole cause of the first

equation's 'uncertainty' and that the assumed parameter distribution of k was simply the result of the distribution of streamflow temperatures on the term $k\theta^{T-20}$.

If the output were still random given constant values of all the inputs, then another source of uncertainty exists. This uncertainty might be due to additional random loadings of the pollutant, possibly from non-point sources. Once again the model could be modified to include these additional loadings if they are knowable. Assuming these additional loadings are not known, a new random parameter could be added to the input variable W or to the right hand side of the equations above that would attempt to capture the impact on C of these additional loadings. A potential problem, however, might be the likely correlation between those additional loadings and the streamflow Q.

While adding model detail removed some 'uncertainty' in the above example, increasing model complexity will not always eliminate or reduce uncertainty in model output. Adding complexity is generally not a good idea when the increased complexity is based on processes whose parameters are difficult to measure, the right equations are not known at the scale of application, or the amount of data for calibration is small compared to the number of parameters.

Even if more detailed models requiring more input data and more parameter values were to be developed, the likelihood of capturing all the processes occurring in a complex system is small. Hence those involved will have to make decisions taking this uncertainty into account. Imprecision will always exist due to less than a complete understanding of the system and the hydrologic processes being modeled. A number of studies have addressed model simplification, but only in some simple cases have statisticians been able to identify just how one might minimize modeling related errors in model output values.

The problem of determining the "optimal" level of modeling detail is particularly important when simulating the hydrologic events at many sites over large areas. Perhaps the best approach for these simulations is to establish confidence levels for alternative sets of models and then statistically compare simulation results. But even this is not a trivial or costless task. Increases in the temporal or spatial resolution typically require considerable data collection and/or processing, model recalibrations, and possibly the solution of stability problems resulting from the numerical methods used in the models. Obtaining and implementing alternative hydrologic simulation models will typically involve considerable investments of money and time for data preparation and model calibration.

What is needed is a way to predict the variability evident in the system shown in Figure 9. Instead of a fixed output vector for each fixed input vector, a distribution of outputs are needed for each performance measure based on fixed inputs (Figure 9) or a distribution of inputs (Figure 10.). Furthermore the model output distribution for each performance measure should 'match' as well as possible the observed distribution of that performance measure.

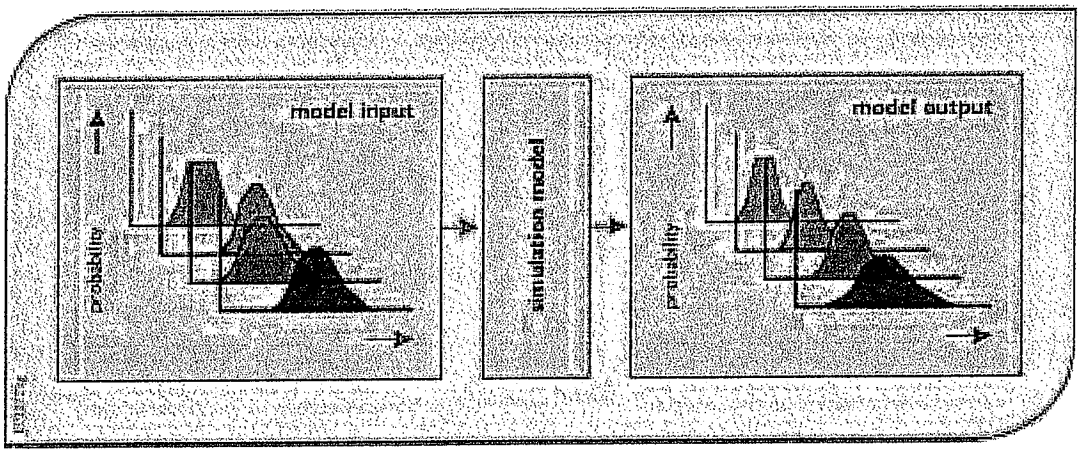

Figure 10. Simulating variable inputs to obtain probability distributions of predicted performance indices that match the probability distributions of observed performance values.

4.1.2 What uncertainty analysis can provide

An uncertainty analysis takes a set of randomly chosen input values (that can include parameter values), passes them through a model (or transfer function) to obtain the distributions (or statistical measures of the distributions) of the resulting outputs. As illustrated in Figure 11, the output distributions can be used to

- Describe the range of potential outputs of the system at some probability level.
- Estimate the probability that the output will exceed a specific threshold or performance measure target value.

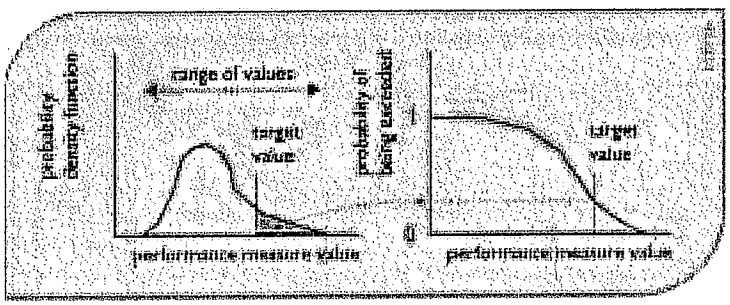

Figure 11. The distribution of performance measures defines range of potential values and the likelihood that a specified target value will be exceeded. The shaded area under the density function on the left represents the probability that the target value will be exceeded. This probability is shown in the probability of exceedance plot on the right.

Common uses for uncertainty analyses are to make general inferences, such as the following:

- Estimating the mean and standard deviation of the outputs.
- Estimating the probability the performance measure will exceed a specific threshold.
- Putting a reliability level on a function of the outputs, e.g., the range of function values that is likely to occur with some probability.
- Describing the likelihood of different potential outputs of the system.

Implicit in any uncertainty analysis are the assumptions that statistical distributions for the input values are correct and that the model is a sufficiently realistic description of the processes taking place in the system. Neither of these assumptions is likely to be entirely correct.

4.2 Sensitivity analyses

"Sensitivity analysis" is aimed at describing how much model output values are affected by changes in model input values. It is the investigation of the importance of imprecision or uncertainty in model inputs in a decision making or modeling process. The exact character of sensitivity analysis depends upon the particular context and the questions of concern. Sensitivity studies can provide a general assessment of model precision when used to assess system performance for alternative scenarios, as well as detailed information addressing the relative significance of errors in various parameters. As a result, sensitivity results should be of interest to the general public, federal and state management agencies, local watershed planners and managers, model users, and model developers.

Clearly, upper level management and the public may be interested in more general statements of model precision, and should be provided such information along with model predictions. On the other hand, detailed studies addressing the significance and interactions among individual parameters would likely be meaningful to model developers and some model users. They can use such data to interpret model results and to identify where efforts to improve models and their input values should be directed.

Initial sensitivity analysis studies could focus on two products:

(1) detailed results to guide research and assist model development efforts, and
(2) calculation of general descriptions of uncertainty associated with model predictions so that policy decisions can reflect both the modeling efforts best prediction of system performance and the precision of such predictions.

In the first case, knowing the relative uncertainty in model projections due to possible errors in different sets of parameters and input data should assist in efforts to improve the precision of model projections. This knowledge should also contribute to a better understanding of the relationships between model assumptions, parameters, data and model predictions.

For the second case, knowing the relative precision associated with model predictions should have a significant effect on policy development. For example, the analysis may show that, given data inadequacies, there are very large error bands associated with some model variables. When such large uncertainties exist, predictions should be used with appropriate skepticism.

Incremental strategies should be explored along with monitoring so that greater experience can accumulate to resolve some of those uncertainties.

Sensitivity analysis features are available in many linear and nonlinear programming (optimization) packages. They identify the changes in the values of the objective function and unknown decision variables given a change in the model input values, and a change in levels set for various constraints (Chapter V). Thus sensitivity analysis addresses the change in "optimal" system performance associated with changes in various parameter values, and also how "optimal" decisions would change with changes in resource constraint levels, or target output requirements. This kind of sensitivity analysis provides estimates of how much another unit of resource would be worth, or what "cost" a proposed change in a constraint places on the optimal solution. This information is of value to those making design decisions.

Various techniques have been developed to determine how sensitive model outputs are to changes in model inputs. Most approaches examine the affects of changes in a single parameter value or input variable assuming no changes in all the other inputs. Sensitivity analyses can be extended to examine the combined effects of multiple sources of error, as well.

Changes in particular model input values can affect model output values in different ways. It is generally true that only a relatively few input variables dominate or substantially influence the values of a particular output variable or performance indicator at a particular location and time. If the range of uncertainty of only some of the output data is of interest, then undoubtedly only those input data that significantly impact on the values of those output data need be included in the sensitivity analysis.

If input data estimates are based on repeated measurements, a frequency distribution can be estimated that characterizes natural variability. The shorter the record of measurements, the greater will be the uncertainty regarding the long-term statistical characteristics of that variability. If obtaining a sufficient number of replicate measurements is not possible, subjective estimates of input data ranges and probability distributions are often made. Using a mixture of subjective estimates and actual measurements does not affect the application of various sensitivity analysis methods that can use these sets or distributions of input values, but it may affect the conclusions that can be drawn from the results of these analyses.

It would be nice to have available accurate and easy-to-use analytical methods for relating errors in input data to errors in model outputs, and to errors in system performance indicator values that are derived from model output. Such analytical methods do not exist for complex simulation models. However methods based on simplifying assumptions and approximations can be used to yield useful sensitivity information. Some of these are reviewed in the remainder of this chapter.

4.2.1 Sensitivity coefficients

One measure of sensitivity is the sensitivity coefficient. This is the derivative of a model output variable with respect to an input variable or parameter. A number of sensitivity

analysis methods use these coefficients. First-order and approximate first-order sensitivity analyses are two such methods that will be discussed later. The difficulty of

1. obtaining the derivatives for many models,
2. needing to assume mathematical (usually linear) relationships when obtaining estimates of derivatives by making small changes of input data values near their nominal or most likely values, and
3. having large variances associated with most hydrologic process models have motivated the replacement of analytical methods by numerical and statistical approaches to sensitivity analysis.

Implicit in any sensitivity analysis are the assumptions that statistical distributions for the input values are correct and that the model is a sufficiently realistic description of the processes taking place in the system. Neither of these assumptions is likely to be entirely correct.

The importance of the assumption that the statistical distributions for the input values are correct is easy to check by using different distributions for the input parameters. If the outputs vary significantly, then the output is sensitive to the specification of the input distributions and hence they should be defined with care. A relatively simple deterministic sensitivity analysis can be of value here (Benaman, 2002). A sensitivity coefficient can be used to measure the magnitude of change in an output variable Q per unit change in the magnitude of an input parameter value P from its base value P_o. Let SI_{PQ} be the sensitivity index for an output variable Q with respect to a change ΔP in the value of the input variable P from its base value P_o. Noting that the value of the output $Q(P)$ is a function of P, the sensitivity index could be defined as

$$SI_{PQ} = [\, Q(P_o + \Delta P) - Q(P_o - \Delta P)\,] / 2\,\Delta P \qquad (1)$$

Other sensitivity indices could be defined (McCuen 1973). Letting the index i represent a decrease and j represent an increase in the parameter value from its base value P_o, the sensitivity index SI_{PQ} for parameter P and output variable Q is could be defined as

$$SI_{PQ} = \{\, |(Q_o - Q_i) / (P_o - P_i)| + |(Q_o - Q_j) / (P_o - P_j)|\,\} / 2 \qquad (2)$$

or

$$SI_{PQ} = \max\{\, |(Q_o - Q_i) / (P_o - P_i)|,\ |(Q_o - Q_j) / (P_o - P_j)|\,\} \qquad (3)$$

A dimensionless expression of sensitivity is the elasticity index, EI_{PQ}, that measures the relative change in output Q for a relative change in input P could be defined as

$$EI_{PQ} = [P_o / Q(P_o)]\, SI_{PQ} \qquad (4)$$

4.2.2 A simple deterministic sensitivity analysis procedure

This deterministic sensitivity analysis approach is very similar those most often employed in the engineering economics literature. It is based on the idea of varying one uncertain parameter value, or set of parameter values, at a time. The ideas are applied to a water quality example to illustrate their use.

The output variable of interest can be any performance measure or indicator. Thus one does not know if more or less of a given variable is better or worse. Perhaps too much and/or too little is undesirable. The key idea is that, whether employing physical measures or economic metrics of performance, various parameters (or sets of associated parameters) are assigned high and low values. Such ranges may reflect either the differences between the minimum and maximum values for each parameter, the 5 and 95 percentiles of a parameters distribution, or points corresponding to some other criteria. The system model is then run with the various alternatives, one at a time, to evaluate the impact of those errors in various sets of parameter values on the output variable.

Table 1 illustrates the character of the results that one would obtain. Here Y_0 is the nominal value of the model output when all parameters assume the estimated best values, and $Y_{i,L}$ and $Y_{i,H}$ are the values obtained by increasing or decreasing the values of the ith set of parameters.

Table 1. Sensitivity of model output Y to possible errors in four parameter sets containing a single parameter or a group of parameters that vary together.

parameter set	low value	nominal	high value
1	$Y_{1,L}$	Y_0	$Y_{1,H}$
2	$Y_{2,L}$	Y_0	$Y_{2,H}$
3	$Y_{3,L}$	Y_0	$Y_{3,H}$
4	$Y_{4,L}$	Y_0	$Y_{4,H}$

A simple water quality example is employed to illustrate this deterministic approach to sensitivity analysis. The analysis techniques illustrated here are just as applicable to complex models. The primary difference is that more work would be required to evaluate the various alternatives with a more complex model, and the model responses might be more complicated.

The simple water quality model is provided by Vollenweider's empirical relationship for the average phosphorus concentration in lakes (Vollenweider, 1976). He found that the phosphorus concentration, P (mg/m^3), is a function of the annual phosphorus loading rate, L (mg/m^2•a), the annual hydraulic loading, q (m/a or more exactly m^3/m^2•a), and the mean water depth, z (m).

$$P = (L/q) / [\, 1 + (z/q)^{0.5} \,] \qquad (5)$$

L/q and P have the same units; the denominator is an empirical factor that compensates for nutrient recycling and elimination within the aquatic lake environment.

Data for Lake Ontario in North America would suggest that reasonable values of the parameters are $L = 680$ mg/m^3; $q = 10.6$ m/a; and $z = 84$ m, yielding $P = 16.8$ mg/m^3. Values of phosphorus concentrations less than 10 mg/m^3 are considered oligotrophic, whereas values greater than 20 mg/m^3 generally correspond to eutrophic conditions. Reasonable ranges reflecting possible errors in the three parameters yield the values in Table 2.

Table 2. Sensitivity of estimates of phosphorus concentration (mg/m^3) to model parameter values. The two right most values in each row correspond to the Low and High values of the parameter, respectively

	parameter value		phosphorus concentration	
	low	high	P_{low}	P_{high}
L — P loading (mg/m²-a)	500	900	12.4	22.3
q — hydraulic loading (m/a)	8	13.5	20.0	14.4
z — mean depth (m)	81	87	17.0	16.6

One may want to display these results so they can be readily visualized and understood. A tornado diagram (Eschenbach, 1992) would show the lower and upper values of P obtained from variation of each parameter, with the parameter with the widest limits displayed on top, and the parameter having smallest limits on the bottom. Tornado diagrams (Figure 12) are easy to construct and can include a large number of parameters without becoming crowded.

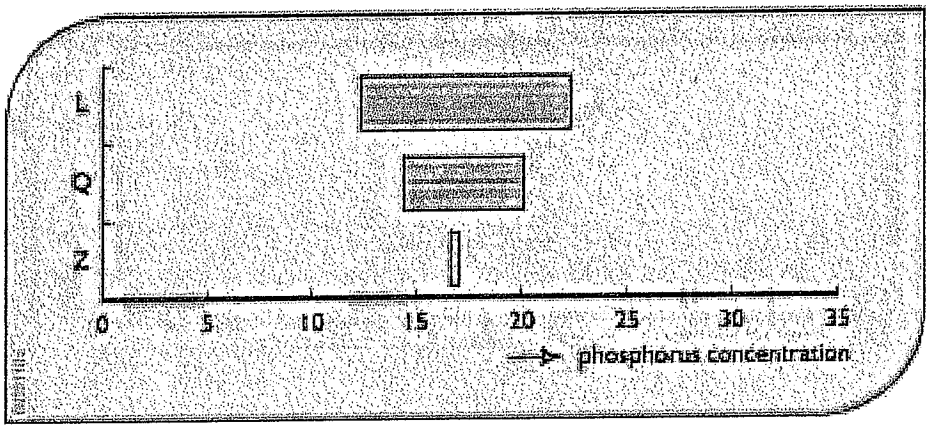

Figure 12. A Tornado diagram showing the range of the output variable representing phosphorus concentrations for high and low values of each of the parameter sets. Parameters are sorted so that the largest range is on top, and the smallest on the bottom.

An alternative to tornado diagrams is a Pareto chart showing the width of the uncertainty range associated with each variable, ordered from largest to smallest. A Pareto chart is illustrated in Figure 13.

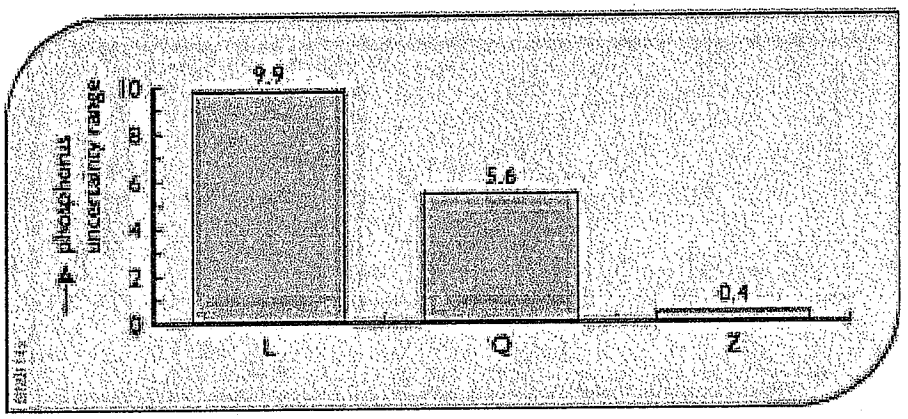

Figure 13. A Pareto Chart showing the range of the output variable representing phosphorus concentrations resulting from high and low values of each parameter set considered.

Another visual presentation is a spider plot showing the impact of uncertainty in each parameter on the variable in question, all on the same graph (Eschenback, 1992; DeGarmo, 1993, p. 401). A spider plot, Figure 14, shows the particular functional response of the output to each parameter on a common scale, so one needs a common metric to represent changes in all of the parameters. Here we use percentage change from the nominal or best values.

Spider plots are a little harder to construct than tornado diagrams, and can generally include only 4 - 5 variables without becoming crowded. However, they provide a more complete view of the relationships between each parameter and the performance measure. In particular, a spider plot reveals nonlinear relationships and the relative sensitivity of the performance measure to (percentage) changes in each variable.

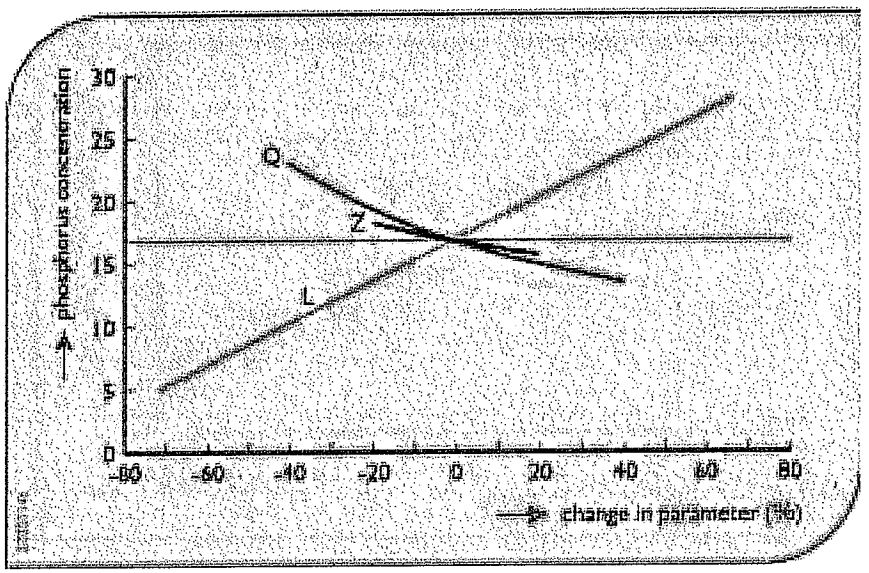

Figure 14. Spider Plot illustrates the relationships between model output describing phosphorus concentrations and variations in each of the parameter sets, expressed as a percentage deviation from their nominal values.

In the spider plot, the linear relationship between P and L and the gentle nonlinear relationship between P and q is illustrated. The range for z has been kept small given the limited uncertainty associated with that parameter.

4.2.3 Multiple errors and interactions

An important issue that should not be ignored is the impact of simultaneous errors in more than one parameter. Probabilistic methods directly address the occurrence of simultaneous errors, but the correct joint distribution needs to be employed. With simple sensitivity analysis procedures, errors in parameters are generally investigated one at a time, or in groups. The idea of considering pairs or sets of parameters is discussed here.

Groups of factors. It is often the case that reasonable error scenarios would have several parameters changing together. For this reason, the alternatives have been called parameter sets. For example, possible errors in water depth would be accompanied with corresponding variations in aquatic vegetation and chemical parameters. Likewise, alternatives related to changes in model structure might be accompanied with variations in several parameters. In other cases, there may be no causal relationship among possible errors (such as model structure

versus inflows at the boundary of the modeled region), but they might still interact to effect the precision of model predictions.

Combinations. If one or more non-grouped parameters interact in significant ways, then combinations of one or more errors should be investigated. However, one immediately runs into a combinatorial problem. If each of m parameters can have 3 values (high, nominal, and low) there are 3^m combinations, as opposed to 2m + 1 if each parameter is varied separately. [For m = 5, the differences are $3^5 = 243$ versus 2(5)+1 = 11.] These numbers can be reduced by considering instead only combinations of extremes so that only $2^m + 1$ cases need be considered [$2^5 + 1 = 33$], which is a more manageable number. However, all of the parameters would be at one extreme or the other, and such situations would be very unusual.

Two factors at a time. A compromise is to consider all pairs of two parameters at a time. There are m(m-1)/2 possible pairs of m parameters. Each parameter has a high and low value. Since there are 4 combinations of high and low values for each pair, there are a total of 2m(m-1) combinations. [For m = 5 there are 40 combinations of two parameters each having two values.]

The presentation of these results could be simplified by displaying for each case only the maximum error, which would result in m(m-1)/2 cases that might be displayed in a Pareto diagram. This would allow identification of those combinations of two parameters that might yield the largest errors and thus are of most concern.

For the water quality example, if one plots the absolute value of the error for all four combinations of high (+) and low (-) values for each pair of parameters, they obtain Figure 15.

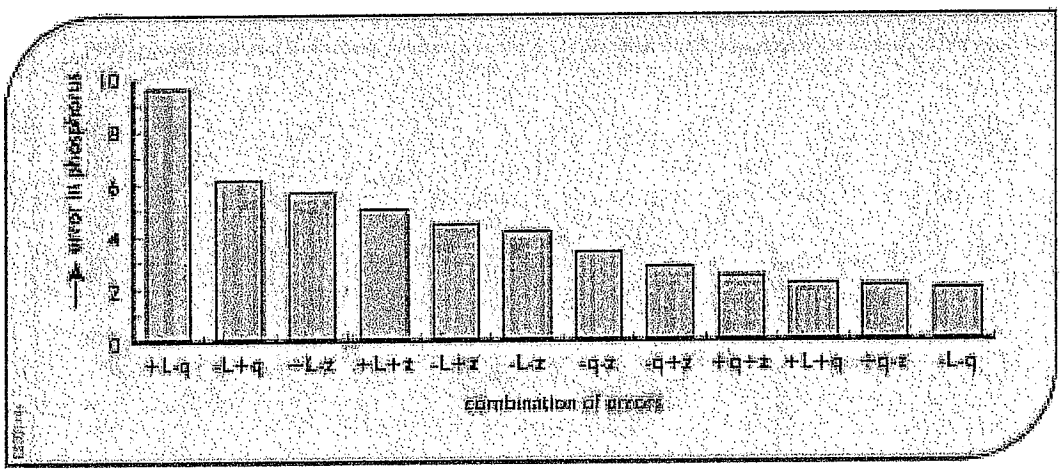

Figure 15. Pareto diagram showing errors in phosphorus concentrations for all combinations of pairs of input parameters errors. A + indicates a high value, and a - indicates a low value for indicated parameter. *L* is the phosphorus loading rate, *q* is the hydraulic loading, and *z* is the mean lake depth.

Considering only the worst error for each pair of variables yields Figure 16.

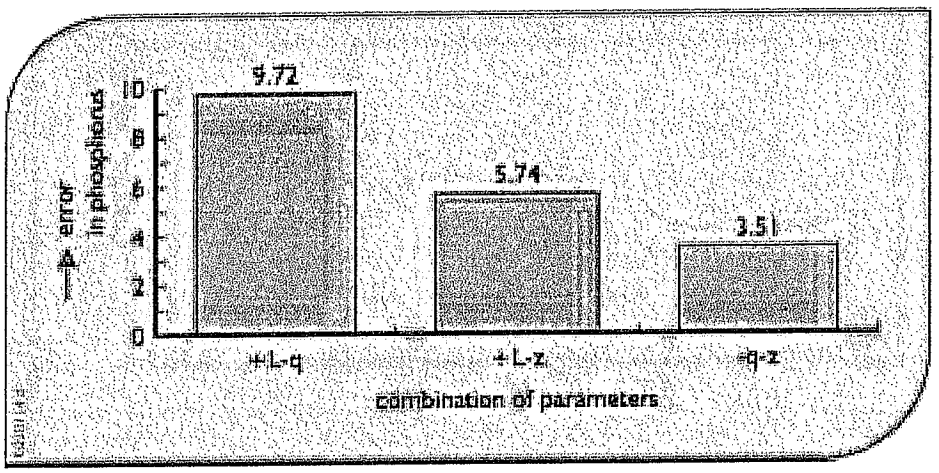

Figure 16. Pareto diagram showing worst error combinations for each pair of input parameters. A '+' indicates a high value, and a '–' indicates a low value for indicated parameter.

Here we see, as is no surprise, that the worst error results from the most unfavorable combination of L and q values. If both parameters have their most unfavorable values, the predicted phosphorus concentration would be 27 mg/m^3.

Looking for non-linearities. One might also display in a Pareto diagram the maximum error for each pair as a percentage of the sum of the absolute values of the maximum error from each parameter separately. The ratio of the joint error to the individual errors would illustrate potentially important nonlinear interactions. If the model of the system and the physical measure or economic metric were strictly linear, then the individual ratios should add to one.

4.2.4 First-order sensitivity analysis

The above deterministic analysis has trouble representing reasonable combinations of errors in several parameter sets. If the errors are independent, it is highly unlikely that any two sets would actually be at their extreme ranges at the same time. By defining probability distributions of the values of the various parameter sets, and specifying their joint distributions, a probabilistic error analysis can be conducted. In particular, for a given performance indicator, one can use multivariate linear analyses to evaluate the approximate impact on the performance indices of uncertainty in various parameters. As shown below, the impact depends upon the square of the sensitivity coefficients (partial derivatives) and the variances and covariances of the parameter sets.

For a performance indicator $I = F(Y)$, which is a function $F(\bullet)$ of model outputs Y, that are in turn a function $g(P)$ of input parameters P, one can use a multivariate Taylor series approximation of F to obtain the expected value and variance of the indicator:

$$E[I] = F(\text{based on mean values of input parameters}) + (1/2)\ \{\Sigma_i\Sigma_j\ [\partial F^2/\partial P_i \partial P_j]\ \mathrm{Cov}\ [P_i, P_j]\ \} \tag{6}$$

and

$$\mathrm{Var}[I] = \Sigma_i\Sigma_j\ (\partial F/\partial P_i)(\partial F/\partial P_j)\ \mathrm{Cov}\ [P_i, P_j] \tag{7}$$

where $(\partial F/\partial P_i)$ are the partial derivative of the function F with respect to P_i evaluated at the mean value of the input parameters P_i, and $\partial F^2/\partial P_i \partial P_j$ are the second partial derivatives. The covariance of two random input parameters P_i and P_j is the expected value of the product of differences between the values and their means.

$$\mathrm{Cov}[P_i, P_j] = E[(P_i - E[P_i])(P_j - E[P_j])] \tag{8}$$

If all the parameters are independent of each other, and the second-order terms in the expression for the mean $E[I]$ are neglected, one obtains

$$E[I] = F(\text{based on mean values of input parameters}) \tag{9}$$

and

$$\mathrm{Var}\ [I] = \Sigma_i\ [\partial F/\partial P_i]^2\ \mathrm{Var}\ [P_i] \tag{10}$$

(Benjamin and Cornell, 1970). Equation 6 for $E[I]$ shows that in the presence of substantial uncertainty, the mean of the output from nonlinear systems is not simply the system output corresponding to the mean of the parameters (Gaven and Burges, 1981, p. 1523). This is true for any nonlinear function.

Of interest in the analysis of uncertainty is the approximation for the variance $\mathrm{Var}[I]$ of indicator I. In Equation 10 the contribution of P_i to the variance of I equals $\mathrm{Var}[P_i]$ times $[\partial F/\partial P_i]^2$, which are the squares of the sensitivity coefficients for indicator I with respect to each input parameter value P_i.

4.2.4.1 An example of first-order sensitivity analysis

It may appear that first-order analysis is difficult because the partial derivatives of the performance indicator I are needed with respect to the various parameters. However, reasonable approximations of these sensitivity coefficients can be obtained from the simple sensitivity analysis described in Table 3, as shown below. In that table, three different parameter sets, P_i, are defined in which one parameter of the set is at its high value, P_{iH}, and one is at its low value, P_{iL}, to produce corresponding values (called high, I_{iH}, and low, I_{iL}) of a system performance indicator I.

Table 3. Approximate parameter sensitivity coefficients.

parameter set	value: low	value: high	sensitivity coefficient
1	I_{1L}	I_{1H}	$[I_{1H}-I_{1L}]/[P_{1H}-P_{1L}]$
2	I_{2L}	I_{2H}	$[I_{2H}-I_{2L}]/[P_{2H}-P_{2L}]$
3	I_{3L}	I_{3H}	$[I_{3H}-I_{3L}]/[P_{3H}-P_{3L}]$

It is then necessary to estimate some representation of the variances of the various parameters with some consistent procedure. For a normal distribution, the distance between the 5 and 95 percentiles is 1.645 standard deviations on each side of the mean, or 2(1.645) = 3.3 standard deviations. Thus, if the high/low range is thought of as approximately a 5-95 percentile range for a normally distributed variate, a reasonable approximation of the variance might be

$$\mathrm{Var}[P_i] = \{ [P_{iH}-P_{iL}]/3.3 \}^2. \qquad (11)$$

This is all that is needed. Use of these average sensitivity coefficients is very reasonable for modeling the behavior of the system performance indicator I over the indicated ranges.

As an illustration of the method of first-order uncertainty analysis, consider the lake quality problem described above. The "system performance indicator" in this case is the model output, the phosphorus concentration P, and the input parameters, now denoted as $X = L$, q, and z. The standard deviation of each parameter is assumed to be the specified range divided by 3.3. Average sensitivity coefficients $\partial P/\partial X$ were calculated. The results are reported in the table below.

Table 4. Calculation of approximate parameter sensitivity coefficients.

varinble X	units	$\delta P/\delta X$	St Dev[X]	$(\delta P/\delta X)^2$ Var[X]	%
L	mg/m^2-yr	0.025	121.21	9.18	75.7
q	m/yr	-1.024	1.67	2.92	24.1
z	m	-0.074	1.82	0.02	0.2

Assuming the parameter errors are independent:

$$\mathrm{Var}[P] = 9.18 + 2.92 + 0.02 = 12.12 \qquad (12)$$

The square root of 12.12 is the standard deviation and equals 3.48. This agrees well with a Monte Carlo analysis reported below.

Note that 100*(9.18/12.12), or about 76% of the total parameter error variance in the phosphorus concentration P is associated in the phosphorus loading rate L and the remaining 24% is associated with the hydrologic loading q. Eliminating the uncertainty in z would have a negligible impact on the overall model error. Likewise, reducing the error in q would at best have a modest impact on the total error.

Due to these uncertainties, the estimated phosphorus concentration has a standard deviation of 3.48. Assuming the errors are normally distributed, and recalling that ± 1.645 standard deviations around the mean define a 5-95 percentile interval, the 5-95 percentile interval would be about

$$16.8 \pm 1.645\ (3.48)\ \mathrm{mg/m^3} = 16.8 \pm 5.7\ \mathrm{mg/m^3} = 11.1 \text{ to } 22.5\ \mathrm{mg/m^3}. \qquad (13)$$

These error bars indicate there is substantial uncertainty associated with the phosphorus concentration P, primarily due to uncertainty in the loading rate L.

The upper bound of 22.6 $\mathrm{mg/m^3}$ is considerably less than the 27 $\mathrm{mg/m^3}$ that would be obtained if both L and q had their most unfavorable values. In a probabilistic analysis with independent errors, such a combination is highly unlikely.

4.2.4.2 Warning on accuracy.

First-order uncertainty analysis is indeed an approximate method based upon a linearization of the response function represented by the full simulation model. It may provide inaccurate estimates of the variance of the response variable for nonlinear systems with large uncertainty in the parameters. In such cases Monte Carlo simulation (discussed below and in Chapter VII) or the use of higher-order approximation may be required. Beck (1987, p. 1426) cites studies that found that Monte Carlo and first-order variances were not appreciably different, and a few studies that found specific differences. Differences are likely to arise when the distributions used for the parameters are bimodal (or otherwise unusual), or some rejection algorithm is used in the Monte Carlo analysis to exclude some parameter combinations. Such errors can result in a distortion in the ranking of predominant sources of uncertainty. However, in most cases very similar results were obtained.

4.2.5 Fractional factorial design method

An extension of first-order sensitivity analysis would be a more complete exploration of the response surface using a careful statistical design. First consider a complete factorial design. Input data are divided into discrete "levels'. The simplest case is two levels. These two levels can be defined as a nominal value, and a high (low) value. Simulation runs are made for all combinations of parameter levels. For n different inputs, this would require 2^n simulation runs. Hence for a three-input variable or parameter problem, 8 runs would be required. If 4 discrete levels of each input variable or parameter were allowed to provide a more reasonable description of a continuous variable, the three-input data problem would require 4^3 or 64 simulation runs. Clearly this is not a useful tool for large regional water resources simulation models.

A fractional factorial design involves simulating only a fraction of what is required from a full factorial design method. The loss of information prevents a complete analysis of the impacts of each input variable or parameter on the output.

To illustrate the fractional factorial design method, consider the two-level with three-input variable or parameter problem. Table 5 below shows the 8 simulations required for a full factorial design method. The '+' and the '–' show the upper and lower levels of each input variable or parameter P_i where $i = 1, 2, 3$. If all 8 simulations were performed, seven possible effects could be estimated. These are the individual effects of the three inputs P_1, P_2, and P_3, the three two-input variable or parameter interactions, $(P_1)(P_2)$, $(P_1)(P_3)$, and $(P_2)(P_3)$, and the one three-input variable or parameter interaction $(P_1)(P_2)(P_3)$.

Table 5. A three-input factorial design.

simulation run	value of input			value of output - variable Y
	P_1	P_1	P_3	
1	-	-	-	Y_1
2	+	-	-	Y_2
3	-	+	-	Y_3
4	+	+	-	Y_4
5	-	-	+	Y_5
6	+	-	+	Y_6
7	-	+	+	Y_7
8	+	+	+	Y_8

Consider an output variable Y, where Y_j is the value of Y in the jth simulation run. Then an estimate of the effect, denoted $\delta(Y|P_i)$, that input variable or parameter P_i has on the output variable Y, is the average of the four separate effects of varying P_i:

For i = 1:

$$\delta(Y \mid P_1) = 0.25\ [\ (Y_2-Y_1)+(Y_4-Y_3)+(Y_6-Y_5)+(Y_8-Y_7)\ ] \tag{14}$$

Each difference in parentheses is the difference between a run in which P_1 is at its upper level and a run in which P_1 is at its lower level, but the other two parameter values, P_2 and P_3, are unchanged. If the effect is equal to 0, then, in this case, P_1 has no impact on the output variable Y.

Similarly the effects of P_2 and P_3, on variable Y can be estimated as:

$$\delta(Y \mid P_2) = 0.25\ \{\ (Y_3-Y_1)+(Y_4-Y_2)+(Y_7-Y_5)+(Y_8-Y_6)\ \} \tag{15}$$

and

$$\delta(Y \mid P_3) = 0.25\ \{\ (Y_5-Y_1)+(Y_6-Y_2)+(Y_7-Y_3)+(Y_8-Y_4)\ \} \tag{16}$$

Consider next the interaction effects between P_1 and P_2. This is estimated as the average of the difference between the average P_1 effect at the upper level of P_2, and the average P_1 effect at the lower level of P_2. This is the same as the difference between the average P_2 effect at the upper level of P_1 and the average P_2 effect at the lower level of P_1:

$$\begin{aligned}\delta(Y \mid P_1, P_2) &= (1/2)\ \{\ [\ (Y_8-Y_7) + (Y_4-Y_3)]/2 - [\ (Y_2-Y_1) + (Y_6-Y_5)]/2\ \} \\ &= (1/4)\ \{\ [\ (Y_8-Y_6)+(Y_4-Y_2)] - [\ (Y_3-Y_1) + (Y_7-Y_5)]\ \}\end{aligned} \tag{17}$$

Similar equations can be derived for looking at the interaction effects between P_1 and P_3, and between P_2 and P_3 and the interaction effects among all three inputs P_1, P_2, and P_3.

Now assume only half of the simulation runs were performed, perhaps runs 2, 3, 5 and 8 in this example. If only outputs Y_2, Y_3, Y_5, and Y_8 are available, for our example:

$$\delta(Y \mid P_3) = \sqcup(Y \mid P_1, P_2) = 0.5\ \{\ (Y_8 - Y_3) - (Y_2 - Y_5)\ \} \tag{18}$$

The separate effects of P_3 and of P_1P_2 are not available from the output. This is the loss in information resulting from fractional instead of complete factorial design.

4.2.6 Monte Carlo sampling methods

The Monte Carlo method of performing sensitivity analyses, illustrated in Figure 16, first selects a random set of input data values drawn from their individual probability distributions. These values are then used in the simulation model to obtain some model output variable values. This process is repeated many times, each time making sure the model calibration is

valid for the input data values chosen. The end result is a probability distribution of model output variables and system performance indices that results from variations and possible errors in all of the input values.

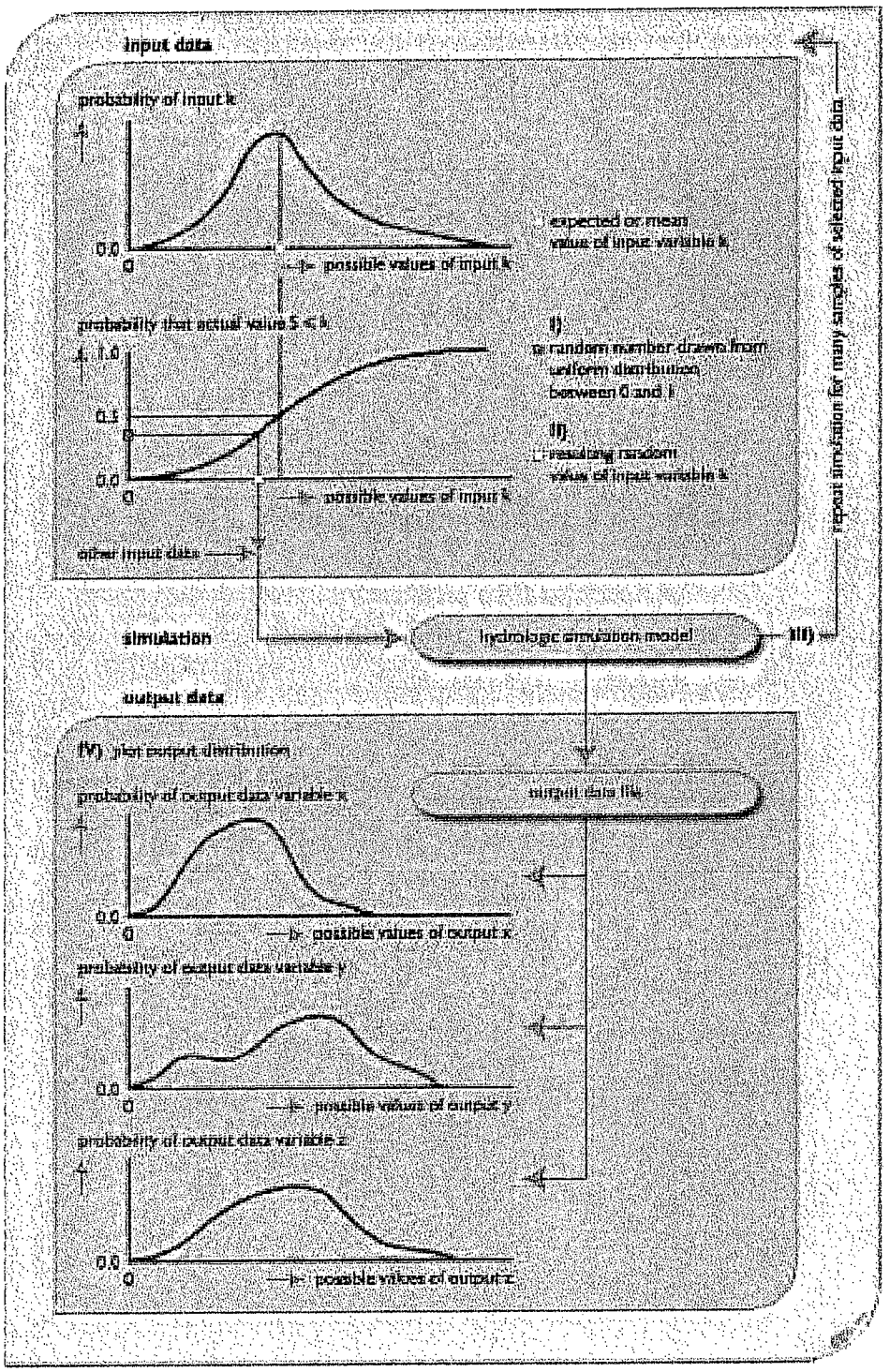

Figure 16. Monte Carlo sampling and simulation procedure for finding distributions of output variable values based on distributions, for specified reliability levels, of input data values. This technique can be applied to one or more uncertain input variables at a time. The output distributions will reflect the combined effects of this input uncertainty over the specified ranges.

Using a simple Monte Carlo analysis, values of all of the parameter sets are selected randomly from distributions describing the individual and joint uncertainty in each, and then the modeled system is simulated to obtain estimates of the selected performance indices. This must be done many times (often well over 100) to obtain a statistical description of system performance variability. The number of replications needed is generally not dependent on the number of parameters whose errors are to be analyzed. One can include in the simulation the uncertainty in parameters as well as natural variability. This method can evaluate the impact of single or multiple uncertain parameters.

A significant problem that arises in such simulations is that some combinations of parameter values result in unreasonable models. For example, model performance with calibration data sets might be inconsistent with available data sets. The calibration process places interesting constraints on different sets of parameter values. Thus, such Monte Carlo experiments often contain checks that exclude combinations of parameter values that are unreasonable. In these cases the generated results are conditioned on this validity check.

Whenever sampling methods are used, one must consider possible correlations among input data values. Sampling methods can handle spatial and temporal correlations that may exist among input data values, but the existence of correlation requires defining appropriate conditional distributions.

One major limitation of applying Monte Carlo methods to estimate ranges of risk and uncertainty for model output variable values, and system performance indicator values based on these output variable values, is the computing time required. To reduce the computing times needed to perform sensitivity analyses using sampling methods, some tricks and as well as stratified sampling methods are available. The discussion below illustrates the idea of a simple modification (or trick) using a "standardized" Monte Carlo analysis. The more general Latin Hypercube Sampling procedure is also discussed.

4.2.6.1 Simple Monte Carlo sampling

To illustrate the use of Monte Carlo sampling methods consider again Vollenweider's empirical relationship, Equation 5, for the average phosphorus concentration in lakes (Vollenweider, 1976). Two hundred values of each parameter were generated independently from normal distributions with the means and variances as shown in Table 6.

The table contains the specified means and variances for the generated values of L, q and z, and also the actual values of the means and variances of the 200 generated values of L, q, z and also of the 200 corresponding generated output phosphorus concentrations, P. Figure 17 displays the distribution of the generated values of P.

Table 6. Monte Carlo analysis of lake phosphorus levels.

parameter	L	q	z	P
	specified means and standard deviations			
mean standard deviations	680.00 121.21	10.60 1.67	84.00 1.82	— —
	generated means and standard deviations			
mean standard deviations	674.18 130.25	10.41 1.73	84.06 1.82	17.07 3.61

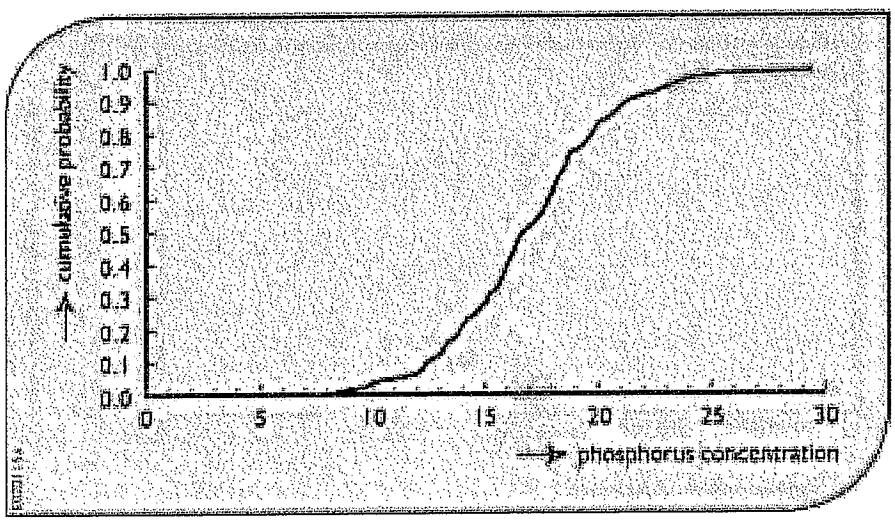

Figure 17. Distribution of lake phosphorus concentrations from Monte Carlo analysis

One can see that given the estimated levels of uncertainty, phosphorus levels could reasonably range from below 10 to above 25. The probability of generating a value greater than 20 mg/m^3 was 12.5%. The 5% to 95 percentile range was 11.1 to 23.4 mg/m^3. In the figure, the cumulative probability curve is rough because only 200 values of the phosphorus concentration were generated, but these are clearly enough to give a good impression of the overall impact of the errors.

4.2.6.2 Sampling uncertainty.

In this example, the mean of the 200 generated values of the phosphorus concentration, P, was 17.07. However a different set of random values would have generated a different set of P values as well. Thus it is appropriate to estimate the standard error, SE, of this average. The standard error equals the standard deviation σ of the P values divided by the square root of the sample size n:

$$SE = \sigma/(n)^{0.5} = 3.61/(200)^{0.5} = 0.25. \qquad (19)$$

From the central limit theorem of mathematical statistics, the average of a large number of independent values should have very nearly a normal distribution. Thus, 95% of the time, the true mean of P should be in the interval $17.1 \pm 1.96\ (0.25)$, or 16.6 to 17.6 mg/m^3. This level of uncertainty reflects the observed variability of P and the fact that only 200 values were generated.

4.2.6.3 Making sense of the results.

A significant challenge with complex models is to determine from the Monte Carlo simulation which parameter errors are important. Calculating the correlation between each generated input parameter value and the output variable value is one way of doing this. As Table 7 below shows, based upon the magnitudes of the correlation coefficients, errors in L were most important, and those in q second in importance.

Table 7. Correlation analysis of Monte Carlo results.

variable	L	q	x	P
L	1			
q	0.079	1		
x	0.1297	-0.139	1	
P	0.851	-0.434	0.144	1

One can also use regression to develop a linear model defining variations in the output based on errors in the various parameters. The results are shown in the Table 8. The fit is very good, and $R^2 = 98\%$. If the model for P had been linear, a R^2 value of 100% should have resulted. All of the coefficients are significantly different from zero.

Note that the correlation between P and z was positive in Table 7, but the regression coefficient for z is negative. This occurred because there is a modest negative correlation between the generated z and q values. Use of partial correlation coefficients can also correct for such spurious correlations among input parameters.

Table 8. Results of Regression Analysis on Monte Carlo Results

	coefficient	standardized error	ratio
intercept	18.605	1.790	10.39
L	0.075	0.000	85.36
Q	-1.068	0.022	-48.54
Z	-0.085	0.021	- 4.08

Finally we display a plot, Figure 18, based on this regression model illustrating the reduction in the variance of P that is due to dropping each variable individually. Clearly L has the biggest impact on the uncertainty in P, and z the least.

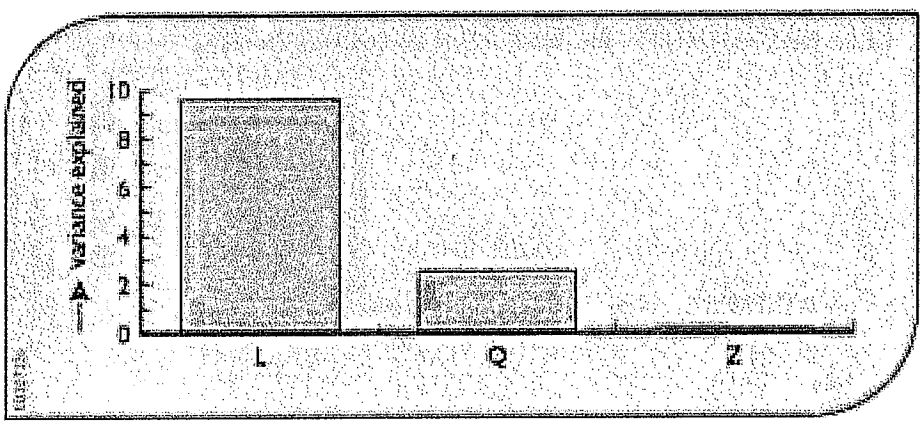

Figure 18. Reduction in the variance of P that is due to dropping from the regression model each variable individually. Clearly L has the biggest impact on the uncertainty in P, and z the least.

4.2.6.4 Standardized Monte Carlo analysis

Using a "standardized" Monte Carlo analysis, one could adjust the generated values of L, q and z above so that the generated samples actually have the desired mean and variance. While making that correction, one can also shuffle their values so that the correlations among the generated values for the different parameters are near zero, as is desired. This was done for the 200 generated values to obtain the statistics shown in Table 9.

Table 9. Standardized Monte Carlo analysis of lake phosphorus levels

parameter	L	q	z	P
	specified means and standard deviations			
Mean	680.00	10.60	84.00	—
Standard deviations	121.21	1.67	1.82	—
	generated means and standard deviations			
Mean	680.00	10.60	84.00	17.03
Standard deviations	121.21	1.67	1.82	3.44

Repeating the correlation analysis from before (shown in Table 10) now yields much clearer results that are in agreement with the regression analysis. The correlation between P and both q and z are now negative as they should be. Because the generated values of the three parameters have been adjusted to be uncorrelated, the signal from one is not confused with the signal from another.

Table 10. Correlation analysis of standardized Monte Carlo results

Variable	L	Q	z	P
L	1.00			
Q	0.01	1.00		
z	0.02	0.00	1.00	
P	0.85	-0.50	-0.02	1.00

The mean phosphorus concentration changed very little. It is now 17.0 instead of 17.1 mg/m^3.

Using control variates with a linear predictive model in conjunction with the standardized Monte Carlo variates, the standard deviation of the errors associated with the 200 observations is only 0.45. Thus the standard error for this estimate of the mean of P is $0.45/(200)^{0.5}$ or just 0.03. Thus this is a highly accurate result. The regressions were also repeated and yielded very similar results. The only real difference was that the parameter estimates had small standard errors and were more significant because of the elimination of correlation between the generated parameters.

4.2.6.5 Generalized likelihood estimation

Beven (1993) and Binley and Beven (1991) suggest a Generalized Likelihood Uncertainty Estimation (GLUE) technique for assessment of parameter error uncertainty using Monte Carlo simulation. It is described as a "formal methodology for some of the subjective elements of model calibration" (Beven, 1989, p. 47). The basic idea is to begin by assigning reasonable ranges for the various parameters and then to draw parameter sets from those ranges using a uniform or some similar (and flat) distribution. These generated parameter sets are then used on a calibration data set so that unreasonable combinations can be rejected, while reasonable values are assigned a posterior probability based upon a likelihood measure which may reflect several dimensions and characteristics of model performance.

Let $L(P_i) > 0$ be the value of the likelihood measure assigned to the ith parameter set's calibration sequence. Then the model predictions generated with parameter set/combination P_i are assigned posterior probability, $p(P_i)$.

$$p(P_i) = L(P_i)/\Sigma_j L(P_j) \qquad (20)$$

These probabilities reflect the form of Bayes theorem, which is well supported by probability theory (Devore, 1991). This procedure should capture reasonably well the dependence or correlation among parameters, because *reasonable* sequences will all be assigned larger probabilities, whereas sequences that are unable to reproduce the system response over the calibration period will be rejected or assigned small probabilities.

However, in a rigorous probabilistic framework, the L would be the likelihood function for the calibration series for particular error distributions. (This could be checked with available goodness-of-fit procedures; for example, Kuczera, 1988.) When relatively ad hoc measures are adopted for the likelihood measure with little statistical validity, the $p(P_i)$ probabilities are best described as pseudo probabilities or "likelihood" weights.

Another concern with this method is the potential efficiency. If the parameter ranges are too wide, a large number of unreasonable or very unlikely parameter combinations will be generated. These will either be rejected or else will have small probabilities and thus little effect on the analysis. In this case the associated processing would be a waste of effort. A compromise is to use some data to calibrate the model and to generate a prior or initial distribution for the parameters that is at least centered in the best range (Beven 1993, p. 48). Then use of a different calibration period to generate the $p(P_i)$ allows an updating of those initial probabilities to reflect the information provided by the additional calibration period with the adopted likelihood measures.

After the accepted sequences are used to generate sets of predictions, the likelihood weights would be used in the calculation of means, variances and quantiles, rather than the customary procedure of giving all the generated realizations equal weight. The resulting conditional distribution of system output reflects the initial probability distributions assigned to parameters, the rejection criteria, and the likelihood measure adopted to assign "likelihood" weights.

4.2.7 Latin hypercube sampling

For the simple Monte Carlo simulations described above, with independent errors, a probability distribution is assumed for each input parameter or variable. In each simulation run, values of all input data are obtained from sampling those individual and independent distributions. The value generated for an input parameter or variable is usually independent of what that value was in any previous run, or what other input parameter or variable values are in the same run. This simple sampling approach can result in a clustering of parameter values and hence both redundancy of information from repeated sampling in the same regions of a distribution and lack of information from no sampling in other regions of the distributions.

A stratified sampling approach ensures more even coverage of the range of input parameter or variable values with the same number of simulation runs. This can be accomplished by dividing the input parameter or variable space into sections and sampling from each section with the appropriate probability.

One such approach, Latin hypercube sampling (LHS), divides each input distribution into sections of equal probability for the specified the probability distribution, and draws one observation randomly from each range. Hence the ranges of input values within each section actually occur with equal frequency in the experiment. These values from each interval for each distribution are randomly assigned to those from other intervals to construct sets of input values for the simulation analysis. Figure 19 shows the steps in constructing a LHS for six simulations involving three inputs P_j (P_1, P_2, and P_3) and six intervals of their respective normal, uniform and triangular probability distributions.

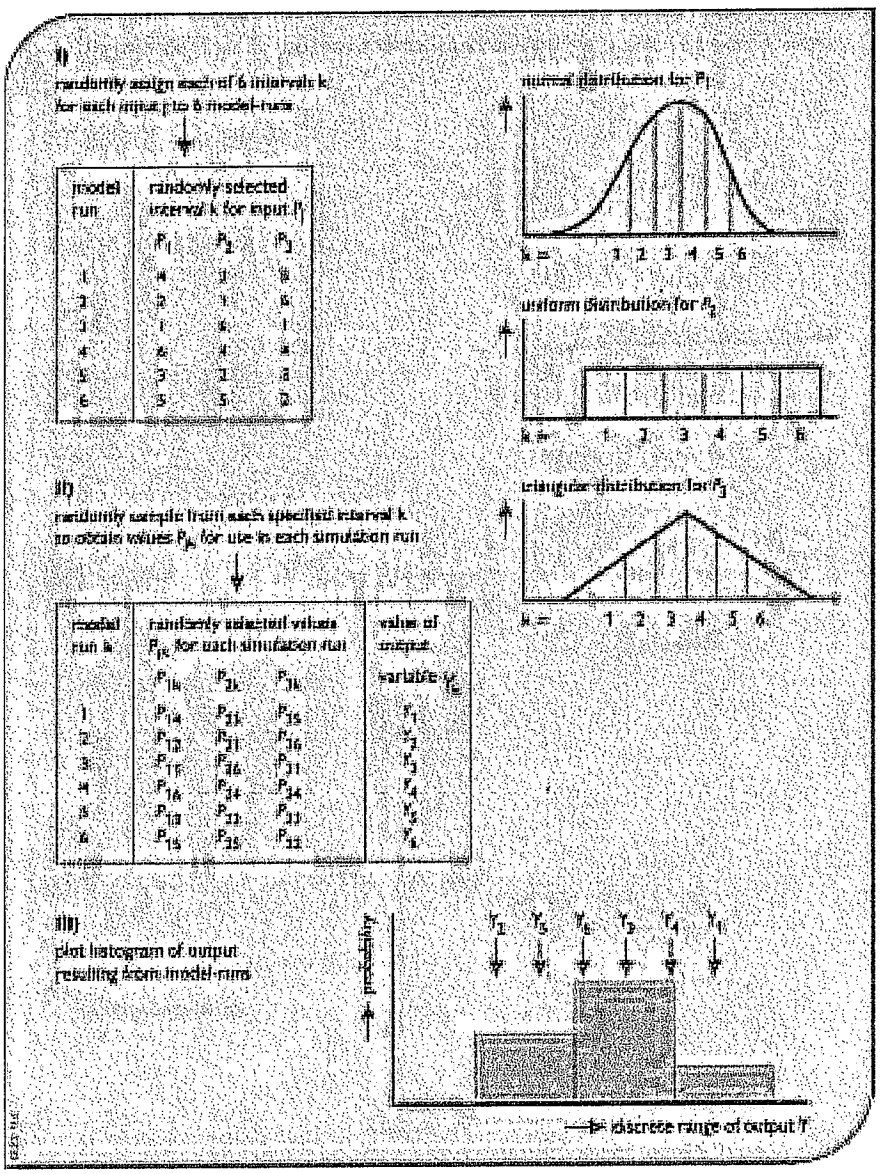

Figure 19. Schematic representation of a Latin hypercube sampling procedure for six simulation runs.

5. Performance indicator uncertainties

5.1 Performance measure target uncertainty

Another possible source of uncertainty is the selection of performance measure target values. For example, consider a target value for a pollutant concentration based on the effect of exceeding it in an ecosystem. Which target value is best or correct? When this is not clear, there are various ways of expressing the uncertainty associated with any target value. One such method is the use of fuzzy sets (Chapter VI). Use of 'grey' numbers or intervals instead of 'white' or fixed target values is another. When some uncertainty or disagreement exists over the selection of the best target value for a particular performance measure it seems to us the most direct and transparent way to do this is to subjectively assume a distribution over a range of possible target values. Then this subjective probability distribution can be factored into the tradeoff analysis, as outlined in Figure 20.

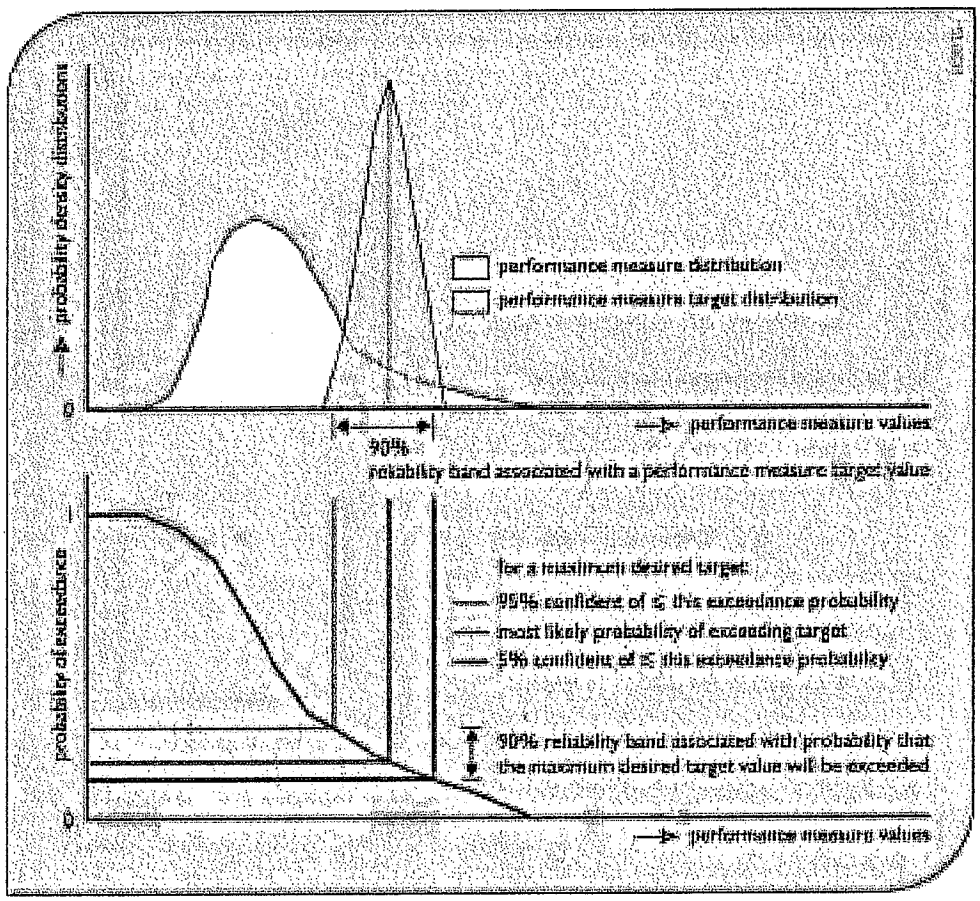

Figure 20. Combining the probability distribution of performance measure values with the probability distribution of performance measure target values to estimate the confidence one has in the probability of exceeding a maximum desired target value.

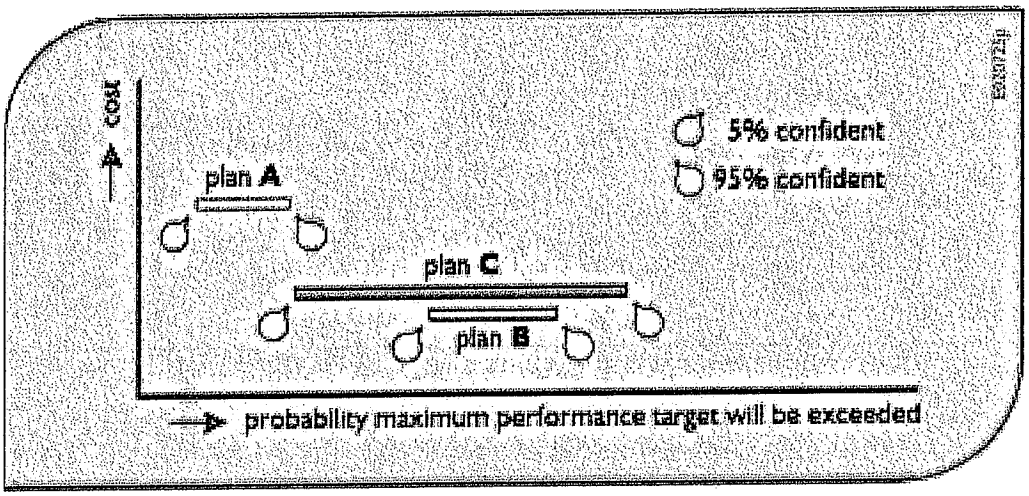

Figure 23. Tradeoffs among cost, reliabilities, and the confidence level of those reliabilities. The relative ranking of plans with respect to the probability of exceeding the desired (maximum limit) target may depend on the confidence given to that probability.

In Figure 23, in terms of cost the plans are ranked, from best to worst, B, C, and A. In terms of reliability at the 90 percent confidence level, they are ranked A, B, and C but at the 50 percent confidence level the ranking is A, C and B.

If the plan evaluation process has difficulty handling all this it may indicate the need to focus the uncertainty analysis effort on just what is deemed important, achievable, and beneficial. Then when the number of alternatives has been narrowed down to only a few that appear to be the better ones, a more complete uncertainty analysis can be performed. There is no need nor benefit in performing sensitivity and uncertainty analyses on all possible management alternatives. Rather one can focus on those alternatives that look the most promising, and then carry out additional uncertainty and sensitivity analyses only when important uncertain performance indicator values demands more scrutiny. Otherwise the work is not likely to affect the decision anyway.

5.2 Distinguishing differences between performance indicator distributions

Simulations of alternative water management infrastructure designs and operating policies require a comparison of the simulation outputs – the performance measures or indicators – associated with each alternative. A reasonable question to ask is are the observed differences statistically significant. Can one really tell if one alternative is better than another or are the observed differences explainable by random variations attributable to variations in the inputs and how the system responds?

This is a common statistical issue that is addressed by standard hypothesis tests (Devore, 1991; Benjamin and Cornell, 1970). Selection of an appropriate test requires that one first resolve what type of change one expects in the variables. To illustrate, consider the comparison of two

One of the challenges associated with defining and including in an analysis the uncertainty associated with a target or threshold value for a performance measure is that of communicating just what the result of such an analysis means. Referring to Figure 20, suppose the target value represents some maximum limit of a pollutant, say phosphorus, concentration in the flow during a given period of time at a given site or region, and it is not certain just what that maximum limit should be. Subjectively defining the distribution of that maximum limit, and considering that uncertainty along with the uncertainty (probability of exceedance function) of pollutant concentrations – the performance measure – one can attach a confidence to any probability of exceeding the maximum desired concentration value.

The 95% probability of exceedance shown on Figure 20, say $P_{0.95}$, should be interpreted as "we can be 95% confident that the probability of the maximum desired pollutant concentration being exceeded will be no greater than $P_{0.95}$." We can be only 5% confident that the probability of exceeding the desired maximum concentration will be no greater than the lower $P_{0.05}$ value. Depending on whether the middle line through the subjective distribution of target values in Figure 20 represents the most likely or median target value, the associated probability of exceedance is either the most likely, as indicated in Figure 20, or that for which we are only 50% confident.

Figure 21 attempts to show how to interpret the reliabilities when the uncertain performance targets are

- minimum acceptable levels that are to be maximized,
- maximum acceptable levels that are to be minimized or
- optimum levels.

An example of a minimum acceptable target level might be the population of wading birds in an area. An example of a maximum acceptable target level might be, again, the phosphorus concentration of the flow in a specific wetland or lake. An example of an optimum target level might be the depth of water most suitable for selected species of aquatic vegetation during a particular period of the year.

For performance measure targets that are not expressed as minimum or maximum limits but that are the 'best' values, referring to Figure 21, one can state that one is 90% confident that the probability of achieving the desired target is no more than B. The 90% confidence level probability of not achieving the desired target is at least A+C. The probability of the performance measure being too low is at least A and the probability of the performance measure being too high is at least C, again at the 90% confidence levels. As the confidence level decreases the bandwidth decreases, and the probability of not meeting the target increases.

Now, clearly there is uncertainty associated with each of these uncertainty estimations, and this raises the question of how valuable is the quantification of the uncertainty of each additional component of the plan in an evaluation process. Will plan evaluators and decision makers

benefit from this additional information, and just how much additional uncertainty information is useful?

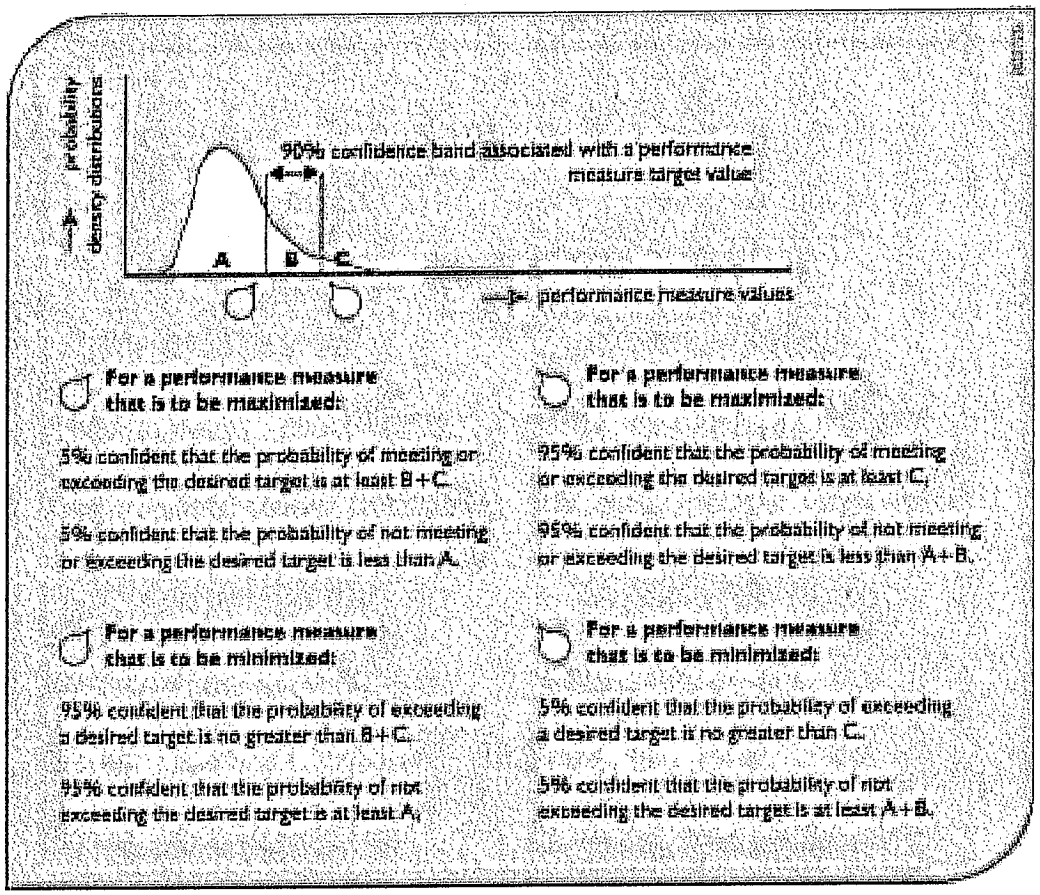

Figure 21. Interpreting the results of combining performance measure probabilities with performance measure target probabilities depends on the type of performance measure. The letters A, B, and C represent proportions of the probability density function of performance measure values. (Hence probabilities A + B + C = 1.)

Now consider again the tradeoffs that need to be made as illustrated in Figure 7. Instead of considering a single target value as shown on Figure 7, assume there is a 90% confidence range associated with that single performance measure target value. Also assume that the target is a maximum desired upper limit (e.g., of some pollutant concentration).

positive (say Y_1 tends to be larger then Y_2), or negative (Y_1 tends to be smaller), or are positive and negative differences are equally likely (there is no difference between Y_1 and Y_2).

Both parametric and non-parametric families of statistical tests are available for paired data. The common parametric test for paired data (a one-sample t test) assumes that the mean of the differences

$$X(i) = Y_1(i) - Y_2(i) \tag{21}$$

are normally distributed. Then the hypothesis of no difference is rejected if the t statistic is sufficiently large, given the sample size n.

Alternatively, one can employ a nonparametric test and avoid the assumption that the differences $X(i)$ are normally distributed. In such a case, one can use the Wilcoxon Signed Rank test. This nonparametric test ranks the absolute values $|X(i)|$ of the differences. If the sum S of the ranks of the positive differences deviates sufficiently from its expected value, $n(n+1)/4$ (were there no difference between the two distributions), one can conclude that there is a statistically significant difference between the $Y_1(i)$ and $Y_2(i)$ series. Standard statistical texts have tables of the distribution of the sum S as a function of the sample size n, and provide a good analytical approximation for $n > 20$ (for example, Devore, 1991). Both the parametric t test and the nonparametric Wilcoxon Signed Rank test require that the differences between the simulated values for each year be computed.

6. Communicating model output uncertainty

Spending money on reducing uncertainty would seem preferable to spending it on ways of calculating and describing it better. Yet attention to uncertainty communication is critically important if uncertainty analyses and characterizations are to be of value in a decision making process. In spite considerable efforts by those involved in risk assessment and management, we know very little about how to ensure effective risk communication to gain the confidence of stakeholders, incorporate their views and knowledge, and influence favorably the acceptability of risk assessments and risk-management decisions.

The best way to communicate concepts of uncertainty may well depend on what the audiences already know about risk and the various types of probability distributions (e.g., density, cumulative, exceedance) based on objective and subjective data, and the distinction between mean or average values and the most likely values. Undoubtedly graphical representations of these ways of describing uncertainty considerably facilitate communication.

The National Research Council (NRC 1994) addressed the extensive uncertainty and variability associated with estimating risk and concluded that risk characterizations should not be reduced to a single number or even to a range of numbers intended to portray uncertainty. Instead, the report recommended managers and the interested public should be given risk characterizations that are both qualitative and quantitative and both verbal and mathematical.

different operating policies. Let Y_1 denote the set of output performance variable values with the first policy, and Y_2 the set of output performance variable values of the second policy. In many cases, one would expect one policy to be better than the other. One measure might be the difference in the mean of the variables; for example is $E[Y_1] < E[Y_2]$?. Alternatively one could check the difference in the median (50 percentile) of the two distributions.

In addition, one could look for a change in the variability or variance, or a shift in both the mean and the variance. Changes described by a difference in the mean or median often make the most sense and many statistical tests are available that are sensitive to such changes. For such investigations parametric and non-parametric tests for paired and unpaired data can be employed.

Consider the differences between "paired" and "unpaired" data. Suppose that the meteorological data for 1941-1990 is used to drive a simulation model generating data as described in Table 11:

Table 11. Possible flow data from a 50-year simulation

1941	Y_1 (1)	Y_2 (1)
1942	Y_1 (2)	Y_2 (2)
1943	Y_1 (3)	Y_2 (3)
1944	Y_1 (4)	Y_2 (4)
1989	Y_1 (49)	Y_2 (49)
1990	Y_1 (50)	Y_2 (50)

Here there is one sample, $Y_1(1)$ through $Y_1(50)$, for policy 1, and another sample, $Y_2(1)$ through $Y_2(50)$, for policy 2. However, the two sets of observations are not independent. For example, if 1943 was a very dry year, then we would expect both $Y_1(3)$ for policy 1 in that year and $Y_2(3)$ for policy 2 to be unusually small. With such paired data, one can use a paired hypothesis test to check for differences. Paired tests are usually easier than the corresponding unpaired tests that are appropriate in other cases. (For example, if one were checking for a difference in average rainfall depth between 1941-1960, and 1961-1990, they would have two sets of independent measurements for the two periods. With such data, one should use a two-sample unpaired test.)

Paired tests are generally based on the differences between the two sets of output, $Y_1(i) - Y_2(i)$. These are viewed as a single independent sample. The question is then are the differences

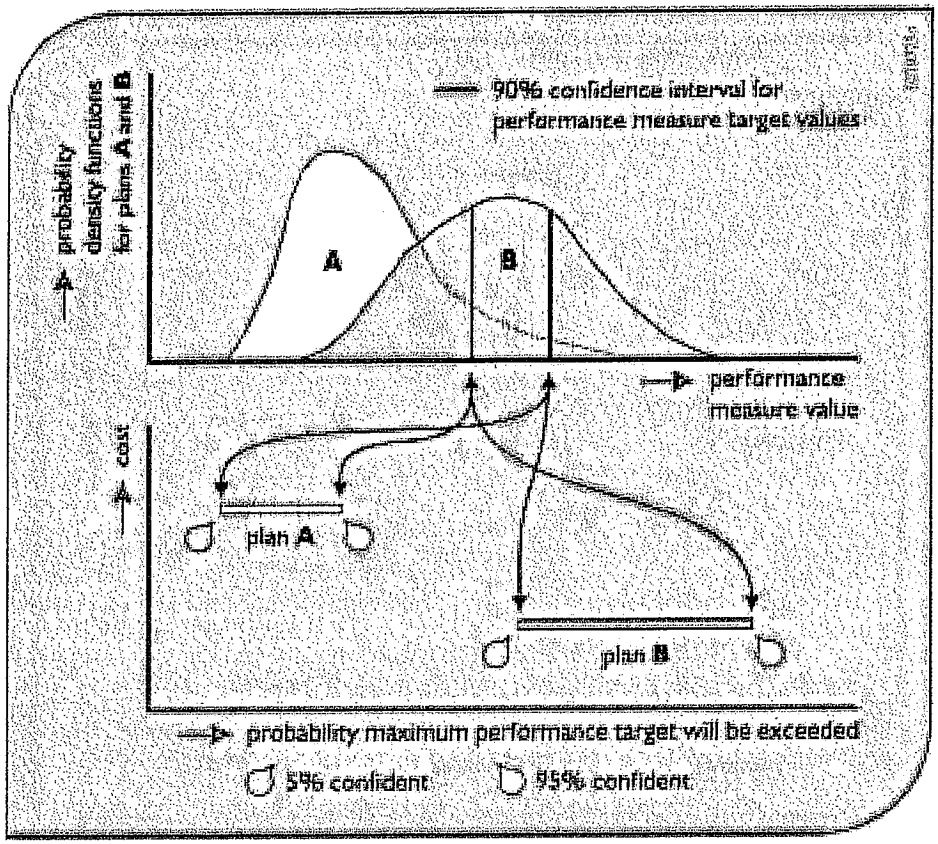

Figure 22. Two plans showing ranges of probabilities, depending on one's confidence, that an uncertain desired maximum (upper limit) performance target value will be exceeded. The 95% confidence levels are associated with the higher probabilities of exceeding the desired maximum target. The 5% confident levels are associated with the more desirable lower probabilities of exceeding the desired maximum target. Plan A with reduced probabilities of exceeding the upper limit costs more than Plan B.

In the case shown in Figure 22, the tradeoff is clearly between cost and reliability. In this example, no matter what confidence one chooses, Plan A is preferred to Plan B with respect to reliability, but Plan B is preferred to Plan A with respect to cost. The tradeoff is only between these two performance indicators or measures.

Consider however a third plan, as shown in Figure 23. This situation adds to the complexity of making appropriate tradeoffs. Now there are three criteria: cost, probability of exceedance (reliability) and the confidence in those reliabilities or probabilities. Add to this the fact that there will be multiple performance measure targets, each expressed in terms of their maximum probabilities of exceedance and the confidence in those probabilities.

In some cases communicating qualitative information about uncertainty to stakeholders and the public in general may be more effective than quantitative information. There are, of course, situations in which quantitative uncertainty analyses are likely to provide information that is useful in a decision-making process. How else can tradeoffs such as illustrated in Figures 10 and 27 be identified? Quantitative uncertainty analysis often can be used as the basis of qualitative information about uncertainty, even if the quantitative information is not what is communicated to the public.

One should acknowledge to the public the widespread confusion regarding the differences between variability and uncertainty. Variability does not change through further measurement or study, although better sampling can improve our knowledge about variability. Uncertainty reflects gaps in information about scientifically observable phenomena.

While it is important to communicate uncertainties and confidence in predictions, it is equally important to clarify who or what is at risk, possible consequences, and the severity and irreversibility of an adverse effect should a target value, for example, not be met. This qualitative information is often critical to informed decision-making. Risk and uncertainty communication is always complicated by the reliability and amounts of available relevant information as well as how that information is presented. Effective communication between people receiving information about who or what is at risk, or what might happen and just how severe and irreversible an adverse effect might be should a target value not be met, is just as important as the level of uncertainty and the confidence associated with such predictions. A two-way dialog between those receiving such information and those giving it can help identify just what seems best for a particular audience.

Risk and uncertainty communication is a two-way street, It involves learning and teaching. Communicators dealing with uncertainty should learn about the concerns and values of their audience, their relevant knowledge, and their experience with uncertainty issues. Stakeholders' knowledge of the sources and reasons for uncertainty needs to be incorporated into assessment and management and communication decisions. By listening, communicators can craft risk messages that better reflect the perspectives, technical knowledge, and concerns of the audience.

Effective communication should begin before important decisions have been made. It can be facilitated in communities by citizen advisory panels. Citizen advisory panels can give planners and decision makers a better understanding of the questions and concerns of the community and an opportunity to test its effectiveness in communicating concepts and specific issues regarding uncertainty.

One approach to make uncertainty more meaningful is to make risk comparisons. For example, a ten parts per billion target for a particular pollutant concentration is equivalent to 10 seconds in over 31 years. If this is an average daily concentration target that is to be satisfied "99 percent," of the time, this is equivalent to an expected violation of less than one day every three months.

Many perceive the reduction of risk by an order of magnitude as though it were a linear reduction. A better way to illustrate orders of magnitude of risk reduction is shown in Figure 24, in which a bar graph depicts better than words that a reduction in risk from one in a 1,000 (10^{-3}) to one in 10,000 (10^{-4}) is a reduction of 90% and that a further reduction to one in 100,000 (10^{-5}) is a reduction 10-fold less than the first reduction of 90%. The percent of the risk that is reduced by whatever measures is a much easier concept to communicate than reductions expressed in terms of estimated absolute risk levels, such as 10^{-5}.

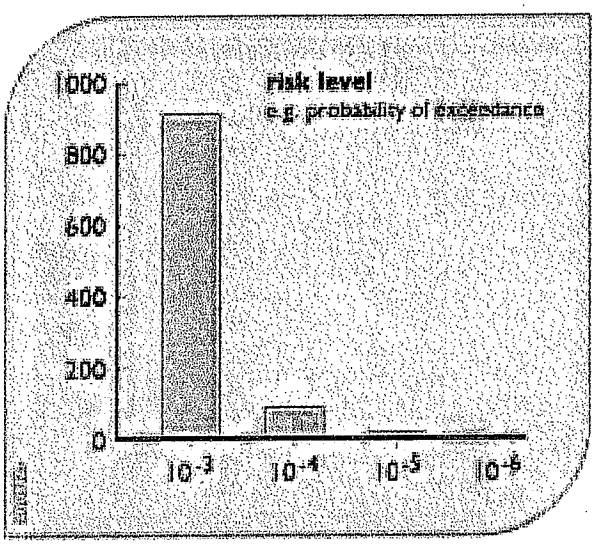

Figure 24. Reducing risk by orders of magnitude is not equivalent to linear reductions.

Risk comparisons can be helpful, but they should be used cautiously and tested if possible. There are dangers in comparing risks of diverse character, especially when the intent of the comparison is seen as minimizing a risk (NRC 1989). One difficulty in using risk comparisons is that it is not always easy to find risks that are sufficiently similar to make a comparison meaningful. How is someone able to compare two alternatives having two different costs and two different risk levels, for example, as is shown in Figure 7? One way is to perform an indifference analysis (Chapter X), but that can lead to different results depending who performs it. Another way is to develop utility functions using weights, where, for example reduced phosphorus load by half is equivalent to a 25 percent shorter hydroperiod in that area, but again each person's utility or tradeoff may differ.

At a minimum, graphical displays of uncertainty can be helpful. Consider the common system performance indicators that include:

- Time-series plots for continuous time-dependent indicators (Figure 25 upper left)
- Probability exceedance distributions for continuous indicators (Figure 25 upper right),
- Histograms for discrete event indicators (Figure 25 lower left), and
- Overlays on maps for space-dependent discrete events (Figure 25 lower right).

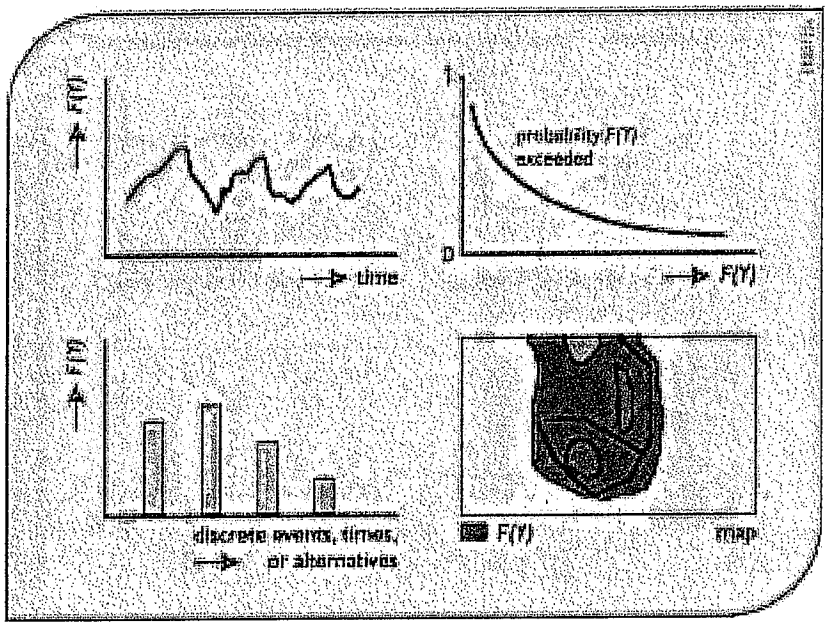

Figure 25. Different types of displays used to show model output Y or system performance indicator values $F(Y)$.

The first three graphs in Figure 25 could show, in addition to the single curve or bar that represents the most likely output, a range of outcomes associated with a given confidence interval. For overlays of information on maps, different colors could represent the spatial extents of events associated with different ranges of risk or uncertainty. Figure 26, corresponding to Figure 25, illustrates these approaches for displaying these ranges.

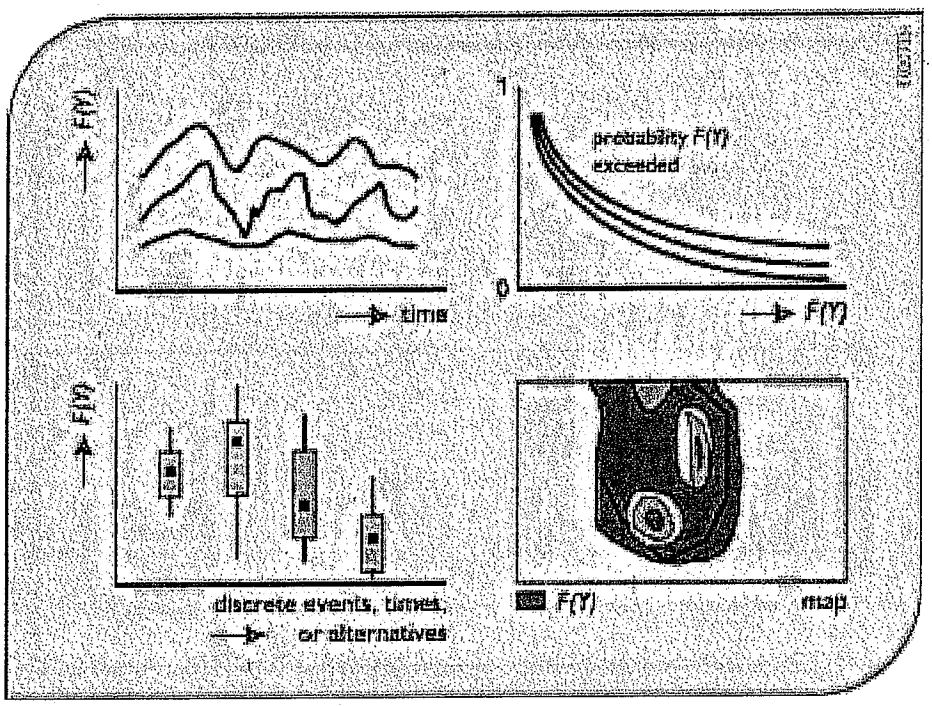

Figure 26. Plots of ranges of possible model output Y or system indicator values $F(Y)$ for different types of displays.

7. Conclusions

This chapter provides an overview of uncertainty and sensitivity analyses in the context of hydrologic or water resources systems simulation modeling. A broad range of tools are available to explore, display, and quantify the sensitivity and uncertainty in predictions of key output variables and system performance indices with respect to imprecise and random model inputs and to assumptions concerning model structure. They range from relatively simple deterministic sensitivity analysis methods to more involved first-order analyses and Monte Carlo sampling methods.

Because of the complexity of many watersheds or river basins, Monte Carlo methods for uncertainty analyses may be a very major and unattractive undertaking. Therefore it is often prudent begin with the relatively simple deterministic procedures. This coupled with a probabilistically based first-order uncertainty analysis method can help quantify the uncertainty in key output variables and system performance indices, and the relative contributions of uncertainty in different input variables to the uncertainty in different output variables and system performance indices. These relative contributions may differ depending upon which output variables and indices are of interest.

A sensitivity analysis can provide a systematic assessment of the impact of parameter value imprecision on output variable values and performance indices, and of the relative contribution of errors in different parameter values to that output uncertainty. Once the key variables are identified, it should be possible to determine the extent to which parameter value uncertainty can be reduced through field investigations, development of better models, and other efforts.

Model calibration procedures can be applied to individual catchments and subsystems, as well as to composite systems. Automated calibration procedures have several advantages including the explicit use of an appropriate statistical objective function, identification of those parameters that best reproduce the calibration data set with the given objective function, and the estimations of the statistical precision of the estimated parameters.

All of these tasks together can represent a formidable effort. However, knowledge of the uncertainty associated with model predictions can be as important to management decision and policy formulation as are the predictions themselves.

No matter how much attention is given to quantifying and reducing uncertainties in model outputs, uncertainties will remain. Professionals who analyze risk, managers and decision makers who must manage risk, and the public who must live with risk and uncertainty, have different information needs and attitudes regarding risk and uncertainty. It is clear that information needs differ among those who model or use models, those who make substantial investment or social decisions, and those who are likely to be impacted by those decisions. Meeting those needs should result in more informed decision making. But it comes at a cost that should be considered along with the benefits of having this sensitivity and uncertainty information.

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Appendix I: Model Calibration Examples

- *Calibration of models in the Murray-Darling Basin*

In the Murray-Darling Basin, in order to preserve water quality, water reliability and the environment, a decision was made in 1995 to restrict water use to the 1993/94 level of development. Computer models of the major tributary streams are now used at the end of each year to determine the annual use target for the previous season based on that level of development. Rules are in place to ensure that long term usage is maintained at the agreed level. Because the models now define the overall water rights of each valley, there are legal requirements to calibrate models and each model is independently audited and certified as being unbiased before being approved as fit for purpose. The key model output of interest is water use but emphasis is also placed on the modeling of downstream flow which impacts the rights of downstream regions. Each model must be calibrated over at least ten years and this often means that changes in infrastructure, operating rules and growth in demand have to be incorporated into the calibration run. Calibration reports contain plots of modeled and observed water use, storage behavior and flow and statistics such as mean error, correlation coefficients and standard errors. The aim of calibration is to ensure that the model is unbiased and to give confidence to stakeholders.

An issue that is sometimes raised with model development is the role of calibration, where the model is fine-tuned to match the observed data, and validation where the model is tested against data that was not used in the calibration process to get an independent assessment of the model's accuracy. For the Murray River, because of the variability of our climate, we like to calibrate our model against a long period of data including the most recent years when the current operating rules were being used and the historical data is generally the most reliable. Validation is considered to be less important and is typically carried out using the two or three years of data available following the completion of model calibration.

- *Use of models for Allocating Water in Texas*

Recent legislation in Texas revised the State Water Planning process and mandated the development of water allocation models for every river basin in the state (http://www.tnrcc.state.tx.us/permitting/waterperm/wrpa/permits.html). Similar to the Murray – Darling situation, these models are used to provide estimates of reliability for all permitted water diversions in the state as well as analysis of the effects of all permit applications. Naturalized, or predevelopment, time series of flows were constructed for the basins, and then the effects of developments were added in to achieve models of the current situation. The process of developing the basin models was an iterative, peer reviewed calibration process subject to stakeholder comment at several critical junctures. The naturalized flows and subsequent development of the basins now form an accepted and legal basis for future water allocations. Currently, similar activities are ongoing to provide calibrated and verified models of the state's groundwater aquifers and usage.

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attachment #7

ADDITIONAL COMMENTS ON CALSIM II PERTINENT TO THE TEMPORARY RESTRAINING ORDER

February 7, 2006
By: Arve R. Sjovold

On reading the Court's decision on our temporary restraining order, I tossed over in my mind the defendant's assertion about using CALSIM II for its relative accuracy. As I discussed with Dave Owens, the relative accuracy claim only has credence if they have established an accurate baseline upon which to impose the relative findings. This is of course totally lacking in their studies because the present operations cannot explain why the Delta ecosystem is crashing at existing pumping levels. Until this is done the BOR or DWR cannot make any valid claim that additional pumping will not harm the environment significantly.

More importantly, CALSIM II, as it is presently structured, is not capable of assessing relative harm to the environment. That is because the environmental constraints that affect the projects are hardwired into the software and are left unchanged while they study scenarios with more pumping. It is unrealistic to assume that constraints (most of which have little to do with species and more to do with water quality) developed in adversarial proceedings before the SWRCB when the projects were pumping less water are sufficient to protect the environment at any higher pumping levels. CALSIM II merely assumes that the SWRCB standards are some kind of absolute standards that will protect the environment forever after, independent of pumping levels. In fact, any proposal to increase pumping over historic levels when the standards were adopted should return to the SWRCB for review and adjustment.

It is also noteworthy that CALSIM II's treatment of the environment involves perfect foresight due to the way it is implemented. This foresight is evident in the way CALSIM II uses its indices to set environmental flows in the Delta. Once the model has established (with near perfect foresight) what the coming water year will look like, it is free to then seek to maximize the extraction of water from the Delta without regard for environmental damage. In other words, CALSIM II is far from conservative or objective when it comes to simulating hydrology and operations. What is needed is to remove the present scheme of indices as they are presently used in CALSIM II and to try and configure the model to allow environmental variables to be dependent on simulated operations. The present model construction is ill-suited for environmental impact analysis.

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attachment #8

Musings on a Model: CalSim II in California's Water Community

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ABSTRACT

Computer model results are becoming more prominent in water policy deliberations in California. CalSim II is the most prominent water management model in California, and has become central to a variety of water management and policy issues and controversies. This paper reports on the results of an extensive set of loosely-structured interviews with members of California's technical and policy-oriented water management community regarding the use and development of CalSim II in California. The interviewers reflect on the thoughts of interviewees and how such interview activities can further policy-effective modeling and technical activities for water management. CalSim II is a complex model of a complex part of California's changing multi-purpose water system. As such, analytical controversies and misunderstandings are inevitable. Ideally, a model and its associated data would perform an additional service as a forum to resolve technical controversies and continually improve quantitative understanding of the system. While CalSim II is generally seen as a significant improvement over previous models, a wide variety of ideas are suggested for improvements.

KEYWORDS

CalSim II, water resources planning, water management, regional water planning, model development, Sacramento-San Joaquin Bay-Delta

SUGGESTED CITATION

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INTRODUCTION

Computer models have become increasingly important in the management and planning of California's water resources. The California Department of Water Resources (DWR) and U.S. Bureau of Reclamation (USBR) jointly developed CalSim II to model the State Water Project and Central Valley Project (SWP and CVP, respectively), which form much of the state's surface water storage and inter-regional water delivery infrastructure (DWR 2004).

CalSim II is a simulation model of the CVP and SWP storage and distribution systems that utilizes a linear programming solver in each time-step to route water through a network given user-defined constraints and priority weights. Developers of CalSim (the generalized water resources management model software underlying CalSim II) also developed the Water Resources Simulation Language (WRESL), which acts as an interface between the user and the solver, time-series database, and relational database. CalSim II simulation of the operations of the CVP and SWP systems includes physical, institutional, and regulatory constraints and an objective function composed of priority-weighted operational penalties. California's current regulatory environment is very complex; and that complexity is represented in the model by four regulatory layers: State Water Resources Control Board's Decision (SWRCB) 1485 (D-1485) and SWRCB Decision 1641 (D-1641); Central Valley Improvement Act (CVPIA), Section 3406 (b)(2); and the California Bay-Delta Authority's Environmental Water Account (EWA). While (b)(2) requires that the conditions under D-1485 be known, EWA requires that condition under D-1485, D-1641, and (b)(2) be known. Because the regulatory environments are interdependent, CalSim II simulates each regulatory condition sequentially for one entire year, before moving on to the following year. This sequential simulation of environmental conditions is commonly known as regulatory layers of CalSim II.

While USBR and DWR developed CalSim II for project-related purposes, CalSim II's actual uses have been wide-ranging. As the single official model for California's two largest water projects, CalSim II and its results affect statewide and Central Valley water operations and planning, and are often at the center of technical and policy controversies. Resolution of controversies often requires an initial airing of concerns from all parties, as it is usually difficult to address informally stated technical problems. This is especially true when many parties are involved, representing a wide range of interests and expressing a variety of concerns. As computer model results have played increasingly important roles in policy and planning decisions, technical concerns (and their policy manifestations) have impeded the development and use of serious modeling tools for water management in California. The original and central purpose of this research was to gather the uses, thoughts, and concerns of a broad cross-section of the California water community regarding CalSim II with the intent to facilitate discussion and assessment, and perhaps address these issues more productively. This project also provided background information for a peer review panel convened in November 2003. http://science.calwater.ca.gov/pdf/CALSIM_Review.pdf (Loucks et al. 2003).

Feedback was collected during interviews of 89 individuals who are involved in the management, planning, decision-making, analysis, and/or modeling of California water resources. Information gathered during the interview process includes existing and potential uses of and questions for CalSim II, reasons for selecting this model, views on its strengths and weaknesses, views on alternatives to CalSim II, and features that people would like to see in alternative operations and planning models or in an improved CalSim model. The report to the CALFED Science Program and its peer review panel presents the detailed methodology and summary of these interviews (Ferreira et al. 2004). The collected uses, thoughts, and insights regarding CalSim II should be useful for:

- Purposes of external review,
- Identification and prioritization of further model development activities,
- Education and outreach activities that would make the model (and modeling in general) better understood and more useful, and
- Better practical understanding (and perhaps ultimately better scientific understanding) of modeling and its complex role in water management in California.

Technical discussions usually benefit from open airing of technical concerns. We hope this paper and its underlying report provide such benefits.

For the California water community, this paper provides a concise overview and insights regarding the roles, problems, and concerns for water operations planning modeling. For researchers and technical managers, this study presents and illustrates a qualitative field method for gaining a better understanding of complex and controversial technical topics and highlight some challenges for the development and use of CalSim II and other models of the California water system.

METHODOLOGY

Surveys and interviews are commonly undertaken for research purposes. However, unlike most interview research, the intent of this particular project was not quantitative or scientific hypothesis-testing, but qualitative and applied, to extract from a broad selection of California's water management community their impressions, concerns, and uses for the CalSim II model. As such, a loosely structured interview process with emphasis on clear and verified interviewee statements of their ideas was developed (Bailey 1978). No attempt was made to assess the frequency of ideas contributed by interviewees. The frequency of responses or thoughts was not relevant for most intended purposes of this research. These interviewee-validated statements of uses, impressions, and concerns are available in the appendix of a report (Ferreira et al., 2004), with a systematic consolidation of these comments being presented in the report itself for easier reading and use by model developers, reviewers, users, and policy-makers.

Since most members of the interview team are also active in computer modeling of California water management (albeit not using CalSim), special potential problems and opportunities arose. As such, the process had some elements of a classical participant-observer study (Gans 1967; Whyte 1955), especially as reported in the latter part of this paper. The potential problems of having interviewers interpret interviewee responses based on the interviewers' experiences were mitigated by having multiple interviewers (for all but one interview), with all interviewers reviewing draft summaries of each interview for verisimilitude with interviewee statements. These draft summaries of each interview were then returned to interviewees with ample opportunity for correction or expansion. The interviewers' prior acquaintance with modeling water problems in California provided advantages for understanding many of the points made by interviewees, facilitating consolidation of comments in the report, and hopefully communicating these thoughts for later use.

Interview procedure

The research team developed and followed standardized procedures to arrange and conduct the interviews. Ninety-five individuals from California's water community, including staff from both DWR and USBR (the agencies that created, own, and manage CalSim II) and individuals affiliated with consulting firms, water districts, environmental groups, and universities, were contacted, of whom 89 agreed to participate in the interviews. Potential interviewees were selected from the members of the California statewide long-term planning (California Bulletin 160-03) advisory committee, from discussions with individuals known to be active in development and use of CalSim II, and from suggestions provided during the course of the interviews. A summary of interviewee affiliations is presented in Table 1. After being contacted, interviewees received a document describing the purpose of the CalSim II interviews, the questions they would be asked during the interview, procedures for interview write-up and review, and policies for attribution.

Table 1. Affiliation of interviewees

Affiliation	Number of Interviewees
DWR	23
USBR	13
Public Water Purveyors	18
Other Government Agencies	5
Non-Profit	5
Universities	1
Consultants	24

The research team conducted interviews either individually or in groups, with group sizes ranging from two to five. In total the team conducted 65 interviews (16

groups and 49 individual) between April 30 and August 28, 2003. Each interview followed a common questionnaire (available in Appendix A of Ferreira et al. 2004), focusing on how the individual and his/her organization currently use CalSim II, would like to use the model, or plan to use the model in the future, as well as more open-ended questions to solicit the individual's full range of thoughts and suggestions regarding CalSim II. The responses were extensive, varied, and at times contradictory. Typical interviews lasted one hour, but some lasted as little as half an hour or as long as two and a half hours.

In all but one case at least two interviewers were present for each interview. Each member of the interview team took hand-written notes during the interviews, none of which were tape-recorded. After the interview was completed, the team wrote a summary and sent it to the interviewee or "lead interviewee" for group interviews. The interviewee then had two weeks to revise and/or extend the summary of his or her interview. Each interviewee had the option of having some, all, or none of the interview summary included in the remarks "Not For Attribution." All of the summaries of the interviews with DWR and USBR personnel were designated "Not For Attribution." Interviewees also had the option of submitting separate written statements, documents, or materials for inclusion or citation in an appendix of the report.

After finalizing the summaries, the research team aggregated the comments into a single database, combining both comments "For Attribution" and "Not For Attribution," and then categorized the comments by topic and content. The *Current and Prospective Uses of CalSim II* section presents the range of analysis to which users apply CalSim II. The section entitled *Interviewee Thoughts and Suggestions* describes remarks regarding the perceived strengths and weaknesses of CalSim II. The results presented below are based on what was heard during the interviews and, to the extent possible, do not contain the opinions of the research team. In the subsequent section entitled *Discussion of Results* the interview team presents its own thoughts on CalSim II and its future management and development.

CURRENT AND PROSPECTIVE USES OF CALSIM II

Current uses of CalSim II include policy planning studies, system operations, facility planning, regulatory compliance, model development, water management, impact estimation, and policy evaluation. Interviewees often use CalSim II with other models, as its output serves as input to numerous economic, hydrodynamic, water quality, operations, and other water planning models at both state and local levels. Table 2 presents a sample of interviewees' current and prospective uses of CalSim II; a full listing and discussion appears in Ferreira et al. (2004).

Table 2. Summarized examples of current and prospective uses of CalSim II

Use	Current	Prospective
Planning Studies		
California Water Plan Update	x	x
SWP Reliability Study	x	x
Integrated Water Resources Planning (local)	x	x
Proposed Facilities		
Storage and Conveyance Projects	x	x
Dam Removal		x
Operations		
Water Temperature Management	x	x
Seasonal Planning (local)	x	x
Real-time	x	
Position Analysis	x	x
Regulatory Analysis and Compliance		
FERC Re-licensing	x	x
Local Flow Standards	x	
EIR/EIS	x	x
ESA Consultations	x	x
Evaluation of Management Options		
Water Transfers	x	x
Conjunctive Use	x	x
Groundwater Banking	x	x
Other		
Gaming Exercises	x	x
Hydropower Generation	x	x

INTERVIEWEE THOUGHTS AND SUGGESTIONS

Most interviewee comments relate to CalSim II's strengths and weaknesses, suggestions regarding CalSim II technical support and development, and broad conclusions about the model's effectiveness in meeting the diverse goals of the many users of CalSim II results. Interviewee thoughts and suggestions were classified according to five major categories and 36 subcategories (Table 3). Some of the most prominent themes that emerged from the hundreds of individual comments are summarized below according to five major categories presented in Table 3. The comments in the *Mission* section highlight the purposes and uses of the model. *Administration* refers to how DWR and USBR manage, direct, and supervise CalSim II and related activities. *Implementation* refers to how the CalSim software is applied to the SWP/CVP system. *Inputs* refer to the data required by CalSim II for each model run. Finally, *Software* refers to the general water resources simulation software package, CalSim, and is not specific to its application to the SWP/CVP system. Many other comments, not mentioned below due to limitations on space, appear in the larger report (Ferreira et al. 2004).

Mission

Prior to CalSim II, DWR and USBR had independent models of the Central Valley projects (DWRSIM and PROSIM, respectively). The two models had different sets of hydrologic data and treated project operations differently. There is wide agreement that cooperation between DWR and USBR has improved greatly as a result of their joint modeling effort to develop and maintain CalSim II. In addition, the use of a single, standard modeling tool and data set has greatly improved the general modeling environment in the California water community. Work now focuses more on substantive issues, rather than on differences between competing models.

While there is consensus that CalSim II represents a step forward, there is also consensus that it needs further improvement in a variety of areas. Many interviewees assert that CalSim II developers did not think through the questions that CalSim II would be asked prior to building the model, and so it is poorly suited to address many of the questions for which interviewees need answers. However, many see CalSim II as the only tool available for such questions, especially for modeling the CVP and SWP systems. The limited (or seemingly limited) modeling options for California water mangers leads to the perception that CalSim II is often misused, misapplied, or over-stretched. Some feel

Table 3. Categorization of Thoughts and Suggestions

Major Category	Sub-Category
I. Mission	A. General Comments
	B. Uses of the Model
	C. Model Scope
	D. Consensus Model
	E. Comparative vs. Absolute Applications
	F. Geographic Scope and Scale
	G. Other
II. Administration	A. Support
	B. Documentation
	C. Management of Model Development
	D. Credibility
	E. Revisions and Updates
	F. Calibration
	G. Benchmark Study
III. Implementation	A. Mathematical Formulation
	B. Operations Representation
	C. Model Complexity
	D. Time Step
	E. Model Flexibility
	F. Representation of Management Options
	G. Stability/Sensitivity of Model Results
	H. Geographic Representation
	I. Run Time
	J. Other
IV. Inputs	A. General Comments
	B. Demands
	C. Hydrology
V. Software	A. Solver
	B. GUI (Graphical User Interface)
	C. Output/Post-processor
	D. Database/Data Management Software
	E. DSS (Data Storage System)
	F. WRESL (Water Resources Simulation Language)
	G. Transparency
	H. Simulation vs. Optimization
	I. Other

that DWR and USBR have already invested too much time and money in CalSim II to be able to objectively ask if the model can answer the questions asked of it, and if not, then what can and/or should be done.

A primary area of concern among interviewees is CalSim II's ability to perform comparative and/or absolute analyses. Comparative modeling examines differences between multiple model runs to evaluate the effects that varying a condition, facility, or operating policy will have on the system, while absolute (or predictive) modeling directly estimates what is likely to happen to the system given a single set of inputs. There is general agreement among interviewees that CalSim II is an appropriate tool for comparative studies, but there is no such consensus regarding absolute studies. Many interviewees feel that using CalSim II in absolute mode is risky and/or inappropriate, but they have no other option because there are no other agency-supported alternatives. To that end, many interviewees want DWR and USBR to either improve CalSim II's predictive capabilities or create a predictive companion model. If users are to apply CalSim II in an absolute mode, many believe that detailed documentation of known limitations and weaknesses, a better understanding of the uncertainty associated with results, and additional effort towards the calibration and testing of the model are imperative.

The huge range of expectations that the California water community has for CalSim II exacerbates this problem of perception. Model developers promised that CalSim II would be easy to use and accessible; in reality, it is a complex model of a complex system that requires significant expertise to run and understand. As a result, only a few individuals concentrated in DWR, USBR, and several consulting firms understand the details and capabilities of CalSim II. Thus, much of the rest of the water community feels left in the dark regarding what CalSim II can do, how to use it, and where to find further guidance. This widespread confusion and uncertainty has eroded CalSim II's credibility outside the small circle of knowledgeable users, as it is difficult to trust a tool that one is unfamiliar with and does not understand. Many indicate that reducing these uncertainties would improve the model's credibility.

Administration

Interviewees commonly mentioned a need for more people who can run CalSim II. The current need for model runs outstrips the number of people who can produce them. This situation is likely to worsen as the demand for CalSim II runs continues to grow. CalSim II's complexity is daunting to new and potential users, and so very few individuals can conduct an entire model study and produce good quality CalSim II runs. This shortage of expertise means that DWR and USBR may be unable to produce CalSim II runs quickly, reducing the usefulness of the model, as it is effectively inaccessible due to the lack of qualified modelers. In addition, the narrow circle of knowledgeable CalSim II users contributes to the perception that CalSim II is a "closed shop" available only to a few insiders. Finally, a small group of users limits the power of CalSim II as an analytical tool, as some see CalSim II's potential power and utility expanded by having a broad spectrum of groups representing different perspectives on water management debates. There is also concern that CalSim II analyses are considered "good" or "acceptable" only with the approval of a select group of individuals who are very familiar with California's water system. A larger pool of users is likely to broaden this circle and dilute the influence of individuals. In the absence of expanding this group, or until the number of experienced users has increased sufficiently, there may be value in creating a standing review group or some other method to certify studies. In general, interviewees agree that DWR and USBR should actively seek to expand the group of expert users, especially to include non-agency and non-consulting users.

To further this goal, many interviewees recommend that DWR and USBR create a centralized source of support for CalSim II users. They would like a help desk or website to provide information on assumptions made in the model and guidance regarding model code, logic, and structure. Tutorials for running CalSim II and interpreting its results, software utilities with which to download data and perform statistical analyses of results, answers to common questions, and results from a sample CalSim II run would also further this cause. In addition, the agencies should expand the existing CalSim II training course to address both the logistics of running CalSim II and the subtleties

required to understand the meaning of its output and its appropriate application. A well-publicized user group also could provide many of these services, distributing information to model users from many interest groups efficiently, and thereby expanding the skill base and reducing the perception of CalSim II as a "closed shop." Similarly, many interviewees feel that some CalSim II managers are defensive in the face of criticism and that including more stakeholders in the development process or providing a forum for input from model users will enhance CalSim II's acceptance and credibility.

All users agree that CalSim II needs better documentation of the model, data, inputs, and results. CalSim II is data-driven, and so it requires numerous input files, many of which lack documentation. Documentation of assumptions is spotty and very technical when it exists, making it difficult for anyone other than model developers to understand how CalSim II arrives at its results. Poor documentation of the conceptual model means that it takes a long time for users to answer seemingly trivial questions and it is difficult for new users to learn how to use the model at all. Overall, the lack of clear and comprehensible documentation increases the likelihood of misunderstandings regarding how the model functions and it contributes to the common impression of CalSim II as a "black box" whose inner workings are beyond the comprehension of most users. This also makes CalSim II runs difficult to duplicate, eroding the model's credibility.

CalSim II is still relatively new and so many users are unsure of and thus uncomfortable with its limitations. They want more information on the model's limitations, including a clear description of what the model does and does not do well. In addition, information on the uncertainty associated with CalSim II results in the form of error bounds, ranges for individual values, or statistical parameters (e.g., mean, variance, etc.) would inform users about the limitations of specific outputs, which is particularly important when users run CalSim II in absolute mode.

There is considerable debate about the current and desirable state of CalSim II's calibration and verification. Some efforts have been made to calibrate the model, but many interviewees express concern that this effort is insufficient if the model is to be run in absolute mode. In addition, DWR and USBR have released a benchmark study to provide a baseline case from which users create alternative scenarios and to which they compare results of alternative runs. This benchmark study has changed with ongoing modifications to CalSim II. Many model users and potential users look forward to a complete, unchanging benchmark study to provide a stable point of reference for other analyses.

Implementation

CalSim II is at once both too simple and too complex. Its representation of the SWP and CVP includes many simplifications that raise concerns regarding the accuracy of results. At the same time, CalSim II is so complex that it is difficult to understand and requires several hours to run. Interviewees express numerous concerns about specific details of CalSim II's implementation, only a few concerns which seemed more prominent and informative are addressed here.

CalSim II's complexity reflects the complexity of the California water system. However, this makes the model cumbersome and difficult to learn. The difficulty in learning and running the model has been a source of frustration to many users and potential users, and there is a common consensus among respondents that CalSim II should be more user-friendly so that stakeholders can run the model without hiring consultants. Just as CalSim II is complex and difficult to understand, so are its results. Many interviewees indicate that interpreting CalSim II results requires not only experience with the model, but also knowledge of the CVP/SWP system and of linear programming. Model users require significant time to determine if results are reasonable and very little guidance on this topic is available from model developers. Also, some claim that there are no specific criteria to define a "good" model run or post-processing tools to help visualize, interpret, correct errors, and obtain answers to common questions. There is additional concern that CalSim II's formulation should be more robust so that runs are not user-dependent. Starting from the same point, different model users likely will produce different CalSim II outputs because during a CalSim II run, the model user generally views intermediate results and adjusts model parameters until he/she

reaches an acceptable result. This adds to inconsistencies across CalSim II runs, making results more difficult to interpret. Finally, CalSim II's complexity and its many layers have resulted in a model that requires several hours to run, frustrating planners who need to explore many refinements to alternatives.

Many interviewees are concerned that CalSim II's monthly time step cannot capture hydrologic variability adequately and thus does not compute water exports and export capacity accurately, both of which are significant factors in system operations. The model's inability to capture within-month variations sometimes results in overestimates of the volume of water the projects can export from the Sacramento-San Joaquin Bay-Delta and makes it seem easier to meet environmental standards than it is in real operations. Many of the system's operations function on a shorter time scale and so CalSim II cannot represent them well given its current formulation. On the other hand, it is unclear if reducing the time step would be either more accurate or more useful, given the additional data and assumptions that would be needed to characterize the system. Some fear that moving to a daily time step might worsen some problems due to questions regarding the precise timing of short events.

Interviewees cannot always determine the parameters to which CalSim II is highly sensitive or its overall stability and sensitivity. They feel that the linear programming formulation allows multiple solutions, which can differ considerably. Small changes in CalSim II input can result in large changes in model results, causing difficulties in impact analyses and the defensibility of model results. In addition, some users note that the multiple layers of regulations and operational agreements included in CalSim II may obscure the effects of the change to the system being modeled.

Inputs

Many interviewees indicate that CalSim II represents demands simplistically using out-of-date values and calculations. Specifically, they believe that demands should be based on land use and should be sensitive to economic factors such as the unit price of water. Without a better basis for the demands in CalSim II, many question the model's validity and capabilities.

Some interviewees also want to see further improvement in CalSim II's representation of hydrologic processes. They feel that it is weak enough to undermine the entire model, as errors in this input propagate through each layer of the model. Many claim that CalSim II's hydrology uses data and methods that are decades out of date and rely on too coarse a geographic scale. In addition, some feel that development of a hydrology should be based on land use patterns and include thorough documentation. Despite these significant concerns, interviewees agreed that CalSim II's joint hydrology (agreed upon by both DWR and USBR) is an improvement over those used by each agency for its previous model.

Software

Model users express general frustration with CalSim II's commercial linear programming (LP) solver. They contend that it provides little information on the location of infeasibilities, so that even a knowledgeable individual may need many days to debug a run. In addition, the solver sometimes produces non-unique solutions and running identical scenarios on different computers seems to generate different results. Several model users state that the solver does not provide any of the sensitivity analysis that LP solutions usually offer and gives no indication of which parameters are constrained, so that users have to search for this information on their own. However, many interviewees feel that the use of an optimization engine for CalSim II is a step forward from previous models and that it is appropriate given the regulatory structures that it tries to model. Others are unsure of how the optimization engine works within CalSim II, while some feel that an optimization approach does not make sense given the many constraints of the SWP and CVP systems.

Individual users are developing their own post-processing techniques, creating the potential for inconsistencies between analyses. They would like visual tools with which to present and compare multiple CalSim II runs. Interviewees expressed interest in tools, both computational and especially visual, that would make it easier to compare results across runs.

Users would like a more intuitive, geographically referenced interface to facilitate the understanding of both

inputs and outputs. It would be helpful if the interface could show the current CalSim II schematic, allowing a user to click on a node and see relevant information including input data, metadata, water balances, and information on the location of relevant equations.

Interviewees applaud CalSim II's inherent transparency as a data-driven model. However, some find the vast number of input files required by CalSim II daunting, thus reducing the effective transparency. In addition, CalSim II includes no automated quality control mechanisms for its many input files, resulting in a time-consuming, generally manual process for setting up a CalSim II run that leaves substantial room for error. Interviewees largely agree that CalSim II would be easier to use if it had a simpler and more coherent data management system. Particularly desirable functions include the archiving of calculation files and the ability to conduct multiple traces of dependencies.

DISCUSSION OF RESULTS

The section above is a brief distillation of the remarks heard during the interview process, absent, to the extent possible, of the research team's opinions. They include many of the most common and interesting points raised throughout the interviews. During the analysis of the many interviews, the research team developed its own thoughts regarding CalSim II and its future development and management. While these clearly are informed by the interviews, this section represents the opinions of the research team. Some of these conclusions are similar to those in the report of a subsequent external peer review panel (Loucks et al. 2003). Our conclusions below are organized around three areas.

Broader involvement in development and use

CalSim II is a significant improvement over previous models of the CVP and SWP systems. A publicly available model, CalSim II uses a modeling approach that affords a flexible, expandable, data-driven, and more transparent modeling framework than alternative and previous models. These modeling features are a remarkable achievement for the developers of CalSim II. DWR's and USBR's agreement to use a single model and underlying data sets has facilitated this significant accomplishment. This consensus has allowed the two agencies to devote resources to develop a single tool rather than critiquing each other's model, as seemed common in the days of PROSIM and DWRSIM.

Despite the advancements of the CalSim II modeling efforts, the consensus between DWR and USBR needs to extend beyond the two agencies. Although both agencies have made attempts to include outsiders in the model development process, CalSim II might have been a much better model had a broader range of stakeholders been more integrally involved during its development. The knowledge and expertise that stakeholders could have brought to the fore would have allowed model developers to better represent the operations and water demands of many local water agencies, particularly how local operations interact with and affect the CVP and SWP systems. This would allow model developers to implement more realistic water demands, in terms of both land use and alternative management options available at the local and regional levels. More importantly, the inclusion of stakeholders in the early stages of model development would have provided developers with crucial insight regarding current and prospective modeling needs of the water community and helped broaden the model user community.

The disconnect between CalSim II developers and the broader California water community is one of the greatest obstacles to CalSim II's acceptance. In part, this obstacle stems from the limited institutional charge of model developers to model only the CVP and SWP systems, and not California water management more generally. Broader and more serious effort on the part of CalSim II developers is needed to raise CalSim II's credibility among stakeholders. To gain credibility among stakeholders it is imperative that model developers see CalSim II as "outsiders" see it. That is, DWR and USBR should more fully commit to communication with the wider California water community through a well publicized, open, and available channel. This communication channel should be a way for outsiders to provide feedback to DWR and USBR regarding their modeling needs and for model developers to provide information and assistance to

model users. For CalSim II to be effective for policy and planning purposes it must be seen as more widely accepted by stakeholders, something that seems unlikely to happen unless (i) stakeholders are involved in ongoing model development, (ii) CalSim II is seen as a useful model to stakeholders, and (iii) more people around the state are comfortable using the model and interpreting its results.

Continuous improvement for contemporary problems

A significant consequence of not including more stakeholders in the early phases of CalSim II development is that the current versions of CalSim II are ill-suited for many of the current analysis needs of the broader water community, particularly absolute applications. Current California water management differs considerably from a decade or two ago, when models that were designed for comparative applications were adequate for most analysis needs. Compliance with legislative provisions regarding both the environment and water availability for new land development requires much more accurate and non-comparative quantitative results than before. While CalSim II developers like to promote it as a model best used for comparative analysis, there is a clear need for a model for absolute purposes. Many local agencies and other stakeholders (including DWR) are employing CalSim II to develop non-comparative, absolute estimates of short- and long-term water deliveries. Therefore, given the issues facing California's water resources and the analysis needs of the water community, it seems unrealistic to expect that modelers only will use CalSim II for comparative analysis. Under the mantra of "the best available tool" (in this case the only available tool), CalSim II is being used, and will continue to be used, for many other types of analyses for which it may be ill-suited, including in absolute mode. Considering the setting in which CalSim II exists, its developers should work toward a model appropriate for absolute applications.

For use in absolute applications, CalSim II needs adequate calibration and testing against recent historical data. (Some very preliminary exploratory work has begun in this direction (DWR 2003).) As with any other type of study, calibration and testing results must be accompanied by a self-critical analysis indicating where the model performs well and where it does not, as well as how this will affect studies that use CalSim II results, both in comparative and in absolute mode, and why. This type of self-critical information is essential. Only when model limitations are understood better will CalSim II gain broader and deeper credibility and acceptance within the water community, and needed improvements can be better pursued.

In addition to the need for a model that can be used in absolute mode, there is also widespread demand for a model that encompasses more than just the SWP and the CVP elements of California's inter-tied water system. The desired model or modeling framework would include not only more of California geographically, but also represent a wider range of water management opportunities and options. For CalSim II to be a truly statewide model it needs to cover the Bay Area, Tulare Basin (including the Friant-Kern and Madera canals, eastside San Joaquin reservoirs, and Millerton), Yuba River Basin (for potential water transfer opportunities), Colorado River, Colorado River and Los Angeles aqueducts, and local Southern California projects.

Coupled with a need for greater geographic coverage, CalSim II should include management options available in California at the regional and local levels. Inter- and intra-agency water transfers are now commonplace, as are other management options such as groundwater banking, conjunctive use, desalination, and water conservation. Consequently, to effectively simulate the array of water operations available within the State, CalSim II needs to include a wider range of management options, facilities, and regions. It is vital that those involved in the management of California's water be able to analyze how local, regional, and state facilities and options best go together. California does not currently have a model or modeling framework capable of such integrated analysis, to parallel the kinds of integrated management thinking being pursued at local, regional, and statewide levels.

Accessibility

Along with serving the needs of the water community, acceptance of CalSim II will increase if more people are able to use and understand the model. Consequently, DWR and USBR need to widen the pool

of model users (a problem DWR and USBR managers often note). Unfortunately, the current narrow circle of knowledgeable CalSim II users contributes to the perception that CalSim II is a "closed shop," available only to a few insiders. This perception also raises concerns about conflicts of interest, as skills on which many diverse stakeholders rely are concentrated in the hands of a few consulting firms, DWR, and USBR.

To widen the group of CalSim II users, DWR and USBR should provide a much greater level of user support than presently available. More frequent training workshops, a comprehensive manual/user's guide, a help desk, and online tutorials could supply much needed assistance to current and prospective CalSim II users. Better pre- and post-processing tools should be available to make the input process more automated and less prone to user error and to facilitate comparison, retrieval, viewing, and result interpretation.

Such attempts, however, should not replace thorough model and data documentation and version control, something that CalSim II currently lacks. CalSim II is unavoidably a very complex model and thus requires comprehensive documentation to enable users to understand the model framework and, more importantly, the sources and methodology used in the derivation of input data, including their limitations. It is difficult to attain credibility when the model and data are seen as impenetrable, particularly when model results run counter to many people's understanding of the system. Counterintuitive results are not necessarily infrequent or bad outcomes for a complex model of a complex system serving diverse stakeholders.

Model documentation should include information regarding appropriate uses of the model, data and model limitations, and error bounds on output values specific to the various purposes for which the model can be used. An often-mentioned frustration of many would-be model users is the lack of guidance on (i) how to appropriately interpret model results for various applications and (ii) what constitutes an acceptable model run.

As with any model, it is much easier to perform a good run if the user thoroughly understands what is being modeled. Understanding California's water system allows the model user to determine whether or not a particular run is "good" and to interpret its results. However, this should not be an excuse not to provide guidance on determining what constitutes a good model run and what must be done to attain a good run. If there are people who can evaluate a set of model results and determine if they are appropriate (and if not, how to modify model inputs to achieve adequate results) then that knowledge should be made available in the public domain, perhaps in the form of a post-processor. Such a post-processor should include guidelines for the appropriate interpretations of model results for various types of applications, including the use of monthly model results to assess impacts that depend on operations and processes that occur at a sub-monthly time-scale. Such a post-processor might not be a final certification of a model run, but would provide an initial screening.

A major problem facing CalSim II developers is that the system they try to model is extremely complex, particularly in light of numerous environmental requirements that must be modeled sequentially. While some people criticize CalSim II for doing too much and therefore being too complex, others believe that CalSim II is not comprehensive enough. Consequently, CalSim II is simultaneously seen as both too complex and too simple. This apparent dichotomy can only be resolved if CalSim II is made truly modular. Modularity would allow model users to turn features, regions, or layers of disaggregation on or off depending on their modeling needs. Modularity could also reduce model run time for many purposes and allow model users to apply CalSim II more efficiently in the early stages of screening alternatives.

THEORETICAL CONTEXT

The theme of opening CalSim II to a broader set of users is consistent with a growing body of literature on the value of combining policy and technical processes, rather than letting one lead the other (Sabatier 1999). While much of this literature focuses on how decision makers plan large infrastructure projects or manipulate natural resource systems, their lessons apply to the development and use of CalSim II, a complex model with significant policy implications.

The importance of including affected parties is now broadly accepted in project planning (WCD 2000; Delli Priscoli 2004). Beginning with research in ecosystem dynamics in the 1970s (Holling 1978), the concept of adaptive management and the integral use of computer models in environmental management and policy-making has grown to influence a variety of disciplines. Traditional methods of centralized planning for projects that affect a broad array of stakeholders based on technical expertise have largely given way to more holistic approaches that solicit input from a wider variety of sources and perspectives (NRC 2004). Within water resources management, this approach has been applied to projects as varied as restoration of the Everglades in Florida and the planning and construction of high dams in developing countries (NRC 2003; WCD 2000). The vast majority of the stakeholders interviewed about CalSim II expressed some interest in a more inclusive process for the ongoing development and improvement of the model. This broader literature supports many interviewees' assertion that CalSim II would benefit from their input, as the inclusion of multiple stakeholders in this process is likely to improve both the performance and acceptance of a complex project such as CalSim II (Lee 1993).

DISCONTENT AND MODEL DEVELOPMENT

Based on the concerns voiced by the interviewees during the interview process and on the impressions of the research team there exists significant concern regarding the abilities and applicability of CalSim II to California's large inter-tied water system. A simple reading of the summaries from the interviews could leave one with the impression that discontent with CalSim II in the water community is a serious impediment to the model's success. However, discontent with an analytical tool is not necessarily unhealthy or avoidable. Voiced concerns are a sign that the model is being used, produces useful insights, and encourages more systematic discussions of system details. Concerns also often provide a positive basis for model improvement.

Investments, both in terms of money and time, in analytical tools for decision-making usually arise from discontent with unaided decision-making. Technical development often follows six stages:

1. Informal statements of concerns;
2. Formal statement of concerns;
3. Assessment of concerns;
4. Plans to address concerns;
5. Actions to address concerns;
6. More (and hopefully different) concerns (repeat step 1).

The development process is by no means linear (BDMF, 2000). Stages can overlap and there is still the likelihood that new concerns will arise even after the effort is made to address the original concerns. Thus the development process is circular, reflecting evolution of the model, greater understanding of the system, and changing thoughts regarding management and policy problems.

If the technical end product was useless, its audience would ignore it entirely and the cycle would end without having successfully addressed the concerns. Many concerns will appear internally within the technical development team working on the products; such comments usually require less communication effort since they are already internal to the development team. New concerns also arise as the field problems to which the model is applied change. Such concerns are a sign of success, as the model is considered worthy of being stretched or adapted to address new problems. Finally, some concerns indicate great success from a model when they arise because model users demand further refinements as they ask more probing questions of the system.

In the case of CalSim II both the user community and the development team have raised concerns. Some of these concerns are quite positive in that the model is being asked to address new and expanded problems in more precise ways, going beyond the model's original narrow SWP/CVP scope. Ultimately, the broader the range of individuals involved with the on-going development of the model, the better the product likely will be. The fact that so many individuals have concerns regarding the uses and applicability of CalSim II is a sign that the model is being used and is worthy of on-going applications, discussions, and development.

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An Environmental Review of CalSim-II:

Defining "Full Environmental Compliance" and "Environmentally Preferred" Formulations of the CalSim-II Model

attachment #9

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one of the main problems w/ CalSim II, as I understand it, is that the model treats groundwater as an infinite supply

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Preface

The "Environmental Review of CalSim-II" was undertaken at the request and under the sponsorship of Water For California, a non-profit organization dedicated to sound stewardship of the State's waters. The original work statement given to the Natural Heritage Institute requested that they examine the CalSim-II code to establish the requirements to meet two specific standards: one, to determine what changes in the data inputs and the code would be necessary to capture "full compliance" with the legal mandates under which the State Water Project (SWP) and the Central Valley Project (CVP) operate; and the second, to establish in a similar fashion the changes in data and code which would be required to perform an "an environmentally preferred" analysis.

> This report is prompted by the use of CalSim-II by agencies as the preferred tool for environmental impact analysis, even though the model is constructed as an optimization model for maximizing exports given certain hydrology and constraints. This report raises a number of important questions and issues with regard to the way CalSim-II is being used.

The "full compliance" option was deemed necessary because present operations of the projects are not fully implementing measures sufficient to meet legal and regulatory requirements promulgated to protect and restore important fisheries and habitats. These deficiencies include directives of the State Water Resources Control Board, the CVPIA's Anadromous Fishery Restoration Programs (AFRP), and more. Each affects operational requirements on dam and pumping operations to protect fisheries and Delta water quality standards. It is important for the investigation to determine just how the code treats these legal directives on the operations of projects and to determine how the CalSim-II model could be used to investigate the impact on project operations if these directives were followed.

The "restoration planning" option was held to be necessary because it was plainly apparent that existing operations, even with expected stricter adherence to the spirit of the environmental limitations, were not effective in redressing the damage that has been incurred to the environment over the lives of these projects. Simply put, the projects, including the present format of CALFED, do not appear adequate to restore health to the Delta and the fisheries as was intended by these programs and as directed by the Endangered Species Act. Again the investigation was required to determine what additional requirements and changes might be added to CalSim-II to move us in the direction of environmental restoration.

> We anticipate that implementation of the proposed changes to CalSim-II will elevate environmental objectives to the same level afforded consumptive water uses in water resource decision-making.

This report is prompted by the use of CalSim-II by agencies as the preferred tool for environmental impact analysis, even though the model is constructed as an optimization model for maximizing exports given certain hydrology and constraints. It raises a number of important questions and issues with regard to the way CalSim-II is being used. We anticipate that implementation of the proposed changes to CalSim-II will elevate environmental objectives to the same level afforded consumptive water uses in water resource decision-making.

Water for California
November, 2005

Executive Summary

CalSim-II is being used in almost every significant water planning process underway in California. When the outcome of a planning process hinges on modeling results, even partially, the assumptions and assertions that lead to these results should be accurate and transparent. Unfortunately, the 2003 peer review of CalSim-II raised a number of concerns about the applicability of the model to these important planning processes. The report published here, *An Environmental Review of CalSim-II*, was prepared in order to improve the transparency of CalSim-II and to measure the current version of the model against two important standards. This report is purposely focused on and limited to two specific questions.

1. **Does the representation of environmental regulations and objectives in CalSim-II represent full compliance with current legal requirements?**
2. **Can CalSim-II be used to plan for water management alternatives associated with improve environmental outcomes and habitat restoration?**

This report does not deal with any of the other CalSim-II issues identified in the CalSim-II Peer Review. The Natural Heritage Institute (NHI) was engage to carry our technical analysis needed to answer these questions.

Full Compliance

The first question is posed in order to assure that the current formulation of CalSim-II is consistent with all current environmental regulations on California's water resources. CalSim-II attempts to characterize all components of the regulatory structure. This report reviewed a significant but limited subset of these regulations. Those reviewed were selected based on the experience of a panel of environmental experts. This selection does not imply that characterizations of other regulation in CalSim-II meet the full compliance standard. In fact, it would be very valuable to complete a similar analysis on the model characterization of all environmental regulations.

Results With regards to the Full Compliance standard, NHI identified three areas where the assumptions and assertions in the current version of CalSim-II were at odds with the expert panel's interpretations of existing environmental regulations:

- **CalSim-II uses information not available to real time operators of the California water system.** This allows CalSim-II to relax environmental standards earlier than is the case in actual operations. As a result, the model under-allocates water needed to satisfy existing environmental regulations; in turn, the model makes that water available for export to south of Delta contractors or other uses.
- **CalSim-II is not faithful to Federal law that allocates water to meet ecosystem restoration objectives.** The 1992 Central Valley Project Improvement Act calls for 800 TAF of water to be allocated for environmental regulation and the logic of CalSim-II does not fully honor this requirement.
- **CalSim-II currently includes no requirement to maintain a minimum flow in the San Joaquin River below Friant Dam**, contrary to a court ruling requiring such flows. This allows for allocation of water to urban and agricultural uses in the Friant Service area rather than allocating that water to maintain water in the San Joaquin River.

For each of these deficiencies, this report proposes a series of actions that can be taken in order to improve the performance of the model. These should be considered the minimum steps required to meet the Full Compliance standard for the regulations reviewed as part of this effort.

Restoration Planning

The second question is motivated by the failure to protect and restore the Sacramento-San Joaquin watershed as legally required. Long-term monitoring of the system suggests that threatened and endangered fish populations are in serious jeopardy. A prudent approach to water management planning would use modeling tools that evaluate the impact of various environmental regulations on water deliveries. CalSim-II has not been crafted to include this flexibility.

Results As examples of the kinds of new regulations that may need to be considered in CalSim-II, the expert panel identified the following regulatory changes that the model should be able to accommodate:

- CalSim-II should have the flexibility to shift salinity compliance points to allow more targeted tributary restoration action. For example, changing the location of the Vernalis salinity standard may reduce the burden on the Stanislaus River.
- CalSim-II should have the capacity to shift required salinity profiles in the Delta (X2) to benefit Delta-dependent species.
- CalSim-II should allow for the prioritization of tributary environmental objectives, such as targeted operation of the Nimbus/Folsom system for the American River.
- CalSim-II should allow for the modification of Delta export restrictions to target improvements in the Delta ecosystem.
- CalSim-II should not count, towards the satisfaction of environmental regulations, water that otherwise would have been releases as part of unavoidable reservoir spills.
- CalSim-II should allow for the definition of flow requirements that result in periods of spring high-flow and summer low-flow conditions in Central Valley rivers.

These changes are consistent with the need to comply with existing environmental laws (CEQA, NEPA, ESA) through the evaluation of alternatives, including those that are the most environmental beneficial. Given the historic difficulty associated with return the Central Valley water system to a viable ecosystem, these changes would allow policy makers to engage in more thoughtful restoration planning. This report includes a workplan to implement these changes. The responses to the proposed actions should be considered markers of the long-term utility of CalSim-II for restoration planning.

Conclusion

Having completed this environmental review of the CalSim-II model, we are left with the profound impression that it is not a tool that can – under its current formulation – fully address the legally required water management objectives. CalSim-II is, after all, a tool that has been designed to determine how best to operate the state's hydraulic infrastructure in ways that maximize the satisfaction of contractual demands. This reality is a result of both the history of water model development in California and a general analytical approach that has held sway for decades in the field of water resources planning and analysis. This approach holds that the environment is a constraint on system operations, not one of the objectives for which the system should be managed. In order to create a tool that can investigate water management innovations designed to comply with the law and restore the environment, it is not simply a matter of adjusting a few input parameters. Instead, a reformulation of the model along the lines described in this document is needed.

CalSim-II holds that the environment is a constraint on system operations, not one of the objectives for which the system should be managed. In order to create a tool that can investigate water management innovations designed to comply with the law and restore the environment, it is not simply a matter of adjusting a few input parameters.

This philosophy of including the environment as an objective in water resources management is gaining credence around the world. Unfortunately, in California we cannot get to this point if we limit ourselves to the current version of CalSim-II. On the positive side, it is clear that no one views the current version of CalSim-II as the final and definitive water planning tool. An effort is underway to develop CalSim-III, which will respond to many of the critiques that have been offered about the model in recent months and years.

The conclusions of this report are offered to constructively contribute to this evolution. We feel that they will elevate, when implemented, aquatic ecosystem restoration to a place alongside of the other water management objectives in the system as is consistent with the imperatives of law and policy. A failure to respond to these critiques would demonstrate, on the other hand, that the water management community has little interest in viewing ecosystem restoration as more that a nettlesome constraint that has to be dealt with, preferably in the most minimal fashion. This would represent a division more profound than some varying professional opinions about the best way to model a complex water resource system.

Approximating Natural Systems in Models

When modeling a natural system, especially a complex one like the Delta and the water systems that support life in it, it is important to consider the context for the modeling effort. This section of the report briefly describes some of the systems and processes impacted by water management decisions. The overall goal of this section is to highlight the need for modelers to understand the natural systems they attempt to represent and for stakeholders to understand the rationale behind assumptions used to represent environmental regulations within water management model logic.

The plants, fish, birds, and other animals that are native to California streams, rivers and wetlands evolved to flourish under the particular climatic and hydrologic patterns of their native watersheds. Prior to development, streams routinely flooded outside of their embankments during strong winter storms and heavy periods of spring snowmelt runoff. By late summer streams ran low and in drought years many sections of smaller rivers and streams dried up completely. In the fall, the first rains would refresh streams and rivers and attract anadromous fish like the fall run Chinook salmon to migrate back up into the watershed to spawning grounds in mid-elevation reaches. Dried-up floodplains and wetlands would begin to fill again in time for the migrating waterfowls to find refreshed habitat.

The riparian forest along California's streams also adapted to these conditions and contributed to the character of the ecosystems in California's rivers and streams. Being inundated throughout much of the winter and spring does not harm the willow, alder, cottonwood and other riparian plants, and the shallow waters around their trunks are important habitat for juvenile fish escaping the faster moving waters in the main currents. In addition, the riparian forest provided much of the food for the aquatic life around them as terrestrial bugs dropped into the waters below.

The seasonal pulses of flow down California's rivers and streams into the Delta interacted with the daily and seasonal tidal fluctuations in the San Francisco Bay to create a shifting pattern of freshwater, brackish water and salt water that was shaped by the complex and shifting flow patterns in the Delta itself to form a mosaic of aquatic habitats. This mosaic supported a complex assemblage of Delta resident plants and animals.

> Californians value their native aquatic ecosystems. A system of environmental laws and regulations, including minimum flow requirements and restrictions on water diversions, has been developed in reaction to serious damage to ecosystems including declines and even loss of species and degradation and loss of habitat.

It goes without saying that conditions changed with the onset of water development in California. The building of levees isolated rivers from their floodplains and fragmented the mosaic of ecosystems in the Delta. The construction and operation of dams and diversion works for water extraction changed the natural flow regimes in ways which reduced the amount of flooding and increased the level of flows in managed rivers and streams during the low

flow period. In the Delta, the combined influence of channelization and changes in the flow regime vastly reduced the amount of certain habitat types used by Delta resident species. These changes were counter to the evolutionary tendencies of native plants and animals throughout the system and were often favorable to invasive species.

This synopsis of pre-development California aquatic ecology and the changes that accompanied water development is not intended to serve as a utopian alternative to the highly developed water system that has been constructed in California over the past century. Indeed, the vast majority of Californians, to one degree or another, rely upon the hydraulic manipulations that water development has accomplished. By the same token, Californians value their native aquatic ecosystems. A system of environmental laws and regulations, including minimum flow requirements and restrictions on water diversions, has been developed in reaction to serious damage to ecosystems including declines and even loss of species and the degradation and loss of habitat. This is the environmental regulatory structure that the developers of CalSim-II have attempted to capture in a simulation model of the California water system.

So just what is CalSim-II and how did it come to play such a central role in California water planning? In order to answer these questions a little bit of historical context is required. For several decades, the managers of the Central Valley Project and the State Water Project have used computer models to simulate the operations of their particular projects. The original models, which went by the names of ProSim for the CVP facilities north of the Delta, SanJaSim for the CVP facilities in the San Joaquin Valley, and DWRSim for the SWP facilities, where used to simulate the extent to which facilities could be operated to meet contractual water demands given a set of assumptions regarding legal requirement and the operating environment. They assumed that historic hydrologic conditions were a decent representation of the likely future. The models were not integrated and therefore it was difficult to evaluate the constraints and opportunities imposed by simultaneous operations of the projects. In addition, the models themselves were developed over many years in a somewhat ad hoc manner with new model logic being added over time as new operating and regulatory approaches were articulated. The end result was a set of codes that were complex, relatively unstable, and nearly impossible to navigate and support as many of the original developers had retired or moved on.

By the 1990s this was clearly an untenable situation on several counts. First, the Delta was in crisis. Ecosystem functions were negatively impacted, and salmon and other species were listed under the ESA. Delta water diversions and extraction over a period of decades was understood to be at least a part of the reason for the problems. The Coordinated Operating Agreement between the CVP and the SWP, and the CALFED Bay-Delta Program, called for closer coordination of CVP and SWP operations to respond to the problem and to legal mandates to restore the populations of listed species. Second, the stakeholder community was demanding a more flexible and transparent set of analytical tools at the very time when the pool of competent ProSim, SanJaSim, and DWRSim analysts was dwindling. Finally, advances in the field of water resources analysis and planning were providing more flexible approaches to water resource simulation modeling based on the application of user-defined priorities and preferences rather than the rigid, If-Then rules used in developing the original models. The time was

right to construct a new simulation model of the California water system, and the managers of both the CVP and the SWP committed resources in an effort to accomplish this task.

At this point, a few observations are warranted. While CalSim-II represents an improvement over the original simulation models in terms of its integration of the State's hydraulic infrastructure, it is clearly derivative from those earlier models. Much of the data and logic used in the original models was introduced to CalSim-II. As a result, CalSim-II still seeks to simulate the extent to which facilities could be operated to meet contractual water demands given a set of assumptions regarding the operating and regulatory environment, and assuming that the range of historic hydrologic conditions is representative of future conditions. As in the early codes, the logic of CalSim-II is designed to maximize the degree to which infrastructure can be operated to satisfy contractual demands. In addition, while CalSim-II is more flexible and stable than the earlier codes, it is not transparent to those outside of the relatively small CalSim-II modeling community.

As a result of this situation, significant questions regarding the model's suitability for multi-objective water resource planning have been raised at the very same time that CalSim-II analyses are being used to inform numerous planning and decision-making processes. There exists a nagging suspicion that the model is not amenable to a full consideration of environmental restoration objectives, and there is a real frustration that it is nearly impossible to address this doubt by examining the logic and assumptions contained in CalSim-II.

> This report seeks to evaluate the degree to which CalSim-II captures the critical characteristics of the existing regulatory structure and explore how the model could be used to evaluate the implications of environmental management strategies that more closely mimic the natural hydrologic conditions under which native aquatic plants and animals in California evolved.

This report reviews a subset of CalSim-II logic dealing with environmental regulation and seeks to evaluate the degree to which this subset of the model captures the critical characteristics of the existing regulatory structure. A similar analysis should be completed on the entire model by the official CalSim-II development team. This report also explores how the model could be used to evaluate the implications of environmental management strategies that more closely mimic the natural hydrologic conditions under which native aquatic plants and animals in California evolved. The first goal is to assure that CalSim-II correctly models existing environmental regulations. A second goal is to create a model that can be used to explore objectives that go beyond maximizing deliveries to meet contractual demands and which instead seek to balance the restoration of California's aquatic environment with the demands for urban and agricultural water use.

Background on CalSim II

CalSim-II was developed collaboratively by the California Department of Water Resources and the United States Bureau of Reclamation. It is the primary water supply planning tool employed by the managers that extract water from the Central Valley water system. CalSim-II is being used to support numerous studies (e.g. the Integrated Storage Investigation) and environmental processes (e.g. the Monterey EIR), requiring that the model's logic, structure and limitations and their influence on the conclusions drawn from model output be both understood and accepted as valid by stakeholders involved in these efforts.

Developing a model that can be accepted as credible, relevant, and useful by those with an interest in the model results is a central challenge in the use of all water resource planning models. For the CalSim-II model, this challenge is magnified by the overall complexity of the Central Valley water system, and the scale at which operations need to be represented. An important response to this challenge occurred in 2003 when a panel of nationally recognized experts conducted a peer review of the CalSim-II model and published a strategic review of how the model could appropriately support water planning, management, and operations in California[1]. The peer review, which was managed by the CALFED Bay-Delta Program and published by the Association of Bay Area Governments, produced many important critiques of the overall CalSim-II approach. These included, among others:

> The peer review did not specifically address the manner in which CalSim-II represents the environmental regulations and objectives established for the Central Valley water system.

- Its extreme reliance on the output of other models as CalSim-II model input without adequate consideration of the assumptions implicit in these other models;
- Its rudimentary representation of important groundwater resources in the system; and,
- Its failure to undergo a classic calibration and validation analysis prior to its deployment in numerous water resources decision-making processes.

The peer review did not specifically address, however, the manner in which CalSim-II represents the environmental regulations and objectives established for the Central Valley water system.

This report describes an effort specifically designed to consider the issue of environmental performance and compliance with environmental requirements. In implementing this review, which involved detailed examination of CalSim-II code and model output, two questions were posed:

[1] Close, A., W.M. Hanemann, J.W. Labadie. D.P. Loucks (chair), J.R. Lund, D.C. McKinney, and J.R. Stedinger. 2003. **A Strategic Review of CALSIM II and its Use for Water Planning, Management, and Operations in Central California.** Association of Bay Area Governments. Oakland, California.

1. Does the representation of environmental regulations and objectives in CalSim-II represent full compliance with current legal requirements?
2. Can CalSim-II be used to plan for water management alternatives associated with improve environmental outcomes and habitat restoration?

In formulating a response to these questions, the effort specifically sought to define a series of actions that could be taken to make CalSim-II responsive to these "full environmental compliance" and "environmentally preferred" standards. For this assessment, compliance was defined as representing all current and pertinent environmental laws and regulations in a manner consistent with how they are actually implemented. Environmentally preferred includes environmental restoration measures that might emerge from on-going regulatory processes, different interpretations of existing regulations, or measures that go beyond current regulatory requirements but are appropriate for long-term planning studies. In particular, we are interested in how CalSim-II could be used to evaluate management strategies that contribute to the restoration of aquatic ecosystems and not the perpetuation of the declining situation under the status quo.

This environmental review was funded by Water for California and managed by the Natural Heritage Institute. Owing to its in-house technical capacity using CalSim-II, NHI was responsible for identifying and describing environmentally pertinent details of the CalSim-II model, including details of both the CalSim-II model logic and results from the Common Assumptions Baseline model runs. Through a series of meetings and one-on-one interactions, NHI collaborated with analysts from Wolf and Associates, the Bay Institute, and Environmental Defense to evaluate and measure these details against the full environmental compliance and environmentally preferred standards. NHI then used the results of this collaboration to formulate two distinct work plans that would (i) assure full environmental compliance and (ii) reflect desired and/or anticipated regulatory changes with regard to environmental services in the Central Valley system. The motivation for this effort is that the implementation of these work plans will increase the level of acceptance afforded the CalSim-II model by the environmental stakeholder community. Absent this acceptance, the usefulness of CalSim-II in multi-stakeholder planning and environmental review processes may be unnecessarily compromised.

Scope of the Review Process

In defining the scope of the CalSim-II environmental review, several general observations about the model proved instructive:

- The CalSim-II model treats environmental considerations as constraints on system operations rather than as objectives to be included in the water allocation optimization routine.
- While some environmental constraints are defined for a particular river/reservoir system, others, in particular the accounting logic associated with implementation of section 3406(b)(2) of the Central Valley Project Improvement Act, have system-wide implications.
- There are numerous local and system-wide sets of environmental constraints in CalSim-II, including regulations for 12 Central Valley rivers and creeks, in the Sacramento-San Joaquin Delta and associated with (b)(2) accounting.

The first observation is important because while treating environmental objectives as "constraints" assures that they will be satisfied, it also requires that certain *a priori* assumptions be made in defining the constraints. Some of these assumptions currently apply perfect foresight through the use of water year indices. This foresight influences the manner in which risk tolerance is captured in the CalSim-II water allocation logic that does not correspond with actual operational decisions made in pursuit of environmental objectives.

The second observation has implications because the approach taken in integrating different local regulations into a governing system-wide constraint set can be as important as the definition of the local constraints themselves. For example, the model logic that applies local environmental operations against (b)(2) obligations can be as important as the logic governing the definition of a minimum flow for a particular river reach.

The third observation this report reviewed a significant but limited subset of these regulations. Those reviewed were selected based on the experience of a panel of environmental experts. This selection does not imply that characterizations of other regulation in CalSim-II meet the full compliance standard.

The flow of this document turns first towards the role that water year indices play in the characterization of environmental constraints and objectives, with specific reference to the definition of risk tolerance in CalSim-II. The report then examines a set of specific environmental regulations in greater detail, examining the model logic that governs the establishment of environmental constraints on the CalSim-II water allocation logic. The report closes with detailed workplans designed to move CalSim-II towards full environmental compliance and environmentally preferred standards that were applied during this model review. While much technical detail has been included in the discussion of water year indices and specific environmental regulations, an honest attempt was made to limit the technical detail to those items that have a direct bearing on the proposed work plans. We ask for our reader's patience in working through the technical details and promise that the effort will be rewarded through a fuller capacity to evaluate the proposed workplans found in the final section of the report.

Water Year Indices and the Role of Foresight in CalSim-II Risk Tolerance

CalSim-II considers environmental objectives to be constraints on the water allocation optimization routine. While the current treatment of environmental regulations assures that environmental "constraints" are satisfied before any water is allocated to other purposes, *the model decides whether or not environmental flows are to be met in full* ***in advance*** *of all other allocations*. This reduces the many environmental unknowns and creates more manageable resource allocation problems but it also serves to optimize water exports rather than environmental outcomes.

This approach is inconsistent with the manner in which water resource allocations actually evolve between the months of February and May, when inflows are highly uncertain. Further, the formulation of environmental objectives as constraints removes the possibility that the environmental objectives for the system will benefit from the same level of optimization as other beneficial uses and hides the need to consider the real environmental impacts of water management activity, namely the condition of the ecosystem.

The formulation of environmental objectives as constraints removes the possibility that the environmental objectives for the system will benefit from the same level of optimization as other beneficial uses and hides the need to consider the real environmental impacts of water management activity, namely the condition of the ecosystem.

This approach to modeling environmental compliance is problematic in terms of responding to the two questions posed in this model review. These criteria focus on the actions necessary to restore California's aquatic ecosystems in order to comply with environmental law rather than simply meeting delivery targets. It also calls into question the use of CalSim-II as a tool for environmental impact assessment, since it is changes in the environment associated with specific projects and not the satisfaction of arbitrary constraints which is the critical focus of environmental review.

Discerning the contours of this problem involves understanding the source and environmental application of all the water year indices used in CalSim-II. Before examining specific indices, it is worth pointing out that water year indices are read into CalSim-II from look-up tables, and they are invariant for a 12-month period subsequent to the month in which they are updated. The index values themselves are pre-calculated from the historic 1921-1994 data used as input to the model. In other words, water year types are defined with *perfect foresight*. Text Box 1 presents a summary of indices that govern environmental standards in CalSim-II.

The following text describes these indices in greater detail and highlights the ways in which they are used to establish environmental constraints. This text is followed by a description of how these indices influence environmental constraints in the CalSim-II water allocation routine and, thereby, how this impacts the final service throughout the system vis-à-vis the risk tolerance logic applied to non-environmental deliveries. Prior to continuing, however, it is important to point out that this document's focus indices use, rather than on the scientific justification of the indices themselves, is not to be interpreted

as an acceptance of the actual indices. The use of data from the previous year has an inappropriate impact on the values of the individual indices.

D1485 Indices

Five water year indices defined by D1485 standards are used to determine Delta Outflow requirements, as they would have been executed under Decision 1485. In addition, they are used for accounting purposes in assigning 'costs' to the (b)(2) account. Each of the indices is updated during the February time step and remains invariant for the subsequent 12 months.

Text Box 1: Water Year Indices Used to Define Environmental Constraints

- D1485
  - D1485 Index
  - D1485 Subnormal Snowmelt Index
  - D1485 2-year Index
  - D1485 Fish and Wildlife Standards Index
  - D1485 Project Deficiency Index
- DWR Indices
  - 40-30-30 Sacramento Basin Index
  - 60-20-20 San Joaquin Basin Index
  - Feather River Basin Index
- CVP Indices
  - Shasta Index
  - American River D893 Index
- Miscellaneous
  - Trinity River Index
  - 8-River Index

D1485 WATER YEAR TYPE INDEX:

The D1485 index[2] has 5 levels: 1 = Wet, 2 = Above Normal, 3 = Below Normal, 4 = Dry, 5 = Critically Dry. The index is used in the calculation of the 1485 Fish and Wildlife Index.

D1485 SNOWMELT INDEX:

The D1485 Snowmelt index[3] has 2 levels: 1 = Above Normal, 2 = Sub-Normal. The index is used in defining Minimum Required Delta Outflow (MRDO) requirements under the D1485 regulatory simulation.

D1485 2-YEAR INDEX

The D1485 2-year index[4] has 2 levels: 0 = normal D1485 conditions, 1 = post-Critical Water Year conditions. Analysis of the input data reveals that the post-Critical Water Year conditions do not always follow years with a D1485 index value of 5, or Critically Dry. The index is used in the calculation of the D1485 Fish and Wildlife Index.

D1485 FISH & WILDLIFE STANDARDS INDEX

The D1485 Fish & Wildlife Standards Index is based on the current values of the D1485 Index and the D1485 2-year Index. Essentially, when the D1485 2-year Index is 1, post-Critical Water Year conditions, the value of the D1485 Index is increased by one increment corresponding to the next drier condition. The D1485 Fish and Wildlife Index

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[4] ...\D1485\Run\Lookup\wytype2yr.table

is then used to define the Rio Vista minimum flow requirement[5]. Additionally, this index is used to define Minimum Required Delta Outflow (MRDO) requirements under the D1485 regulatory simulation.

D1485 Project Deficiency Index

The D1485 Project Deficiency Index[6] has 2 levels: 0 = no deficiencies, 1 = deficiencies. This index is used in defining Minimum Required Delta Outflow (MRDO) requirements under D1485 flow requirements.

DWR Indices

Two DWR indices, which are defined in February and remain invariant for the subsequent 12 months, are used for setting minimum flow standards for certain rivers as well as Delta outflow standards.

40-30-30 Sacramento Basin Index

The 40-30-30 Sacramento Basin Index[7] has 5 levels: 1 = Wet, 2 = Above Normal, 3 = Below Normal, 4 = Dry, 5 = Critically Dry. The index is used in i.) defining the volume of water in the (b)(2) account, ii.) determining reservations of (b)(2) water to assure that (b)(2) is not entirely depleted in the fall, iii.) changing the salinity standards in the Delta, iv.) changing the Minimum Required Delta Outflow[8], and v.) defining the Rio Vista minimum flow requirement[9].

60-20-20 San Joaquin Basin Index

The 60-20-20 San Joaquin Basin Index[10] has 5 levels: 1 = Wet, 2 = Above Normal, 3 = Below Normal, 4 = Dry, 5 = Critically Dry. The index is used to define minimum flow requirements in certain river reaches. Flow requirements affected by the index include the minimum flows on the Calaveras and Mokelumne River, the San Joaquin ERPP (Ecosystem Restoration Program Plan) flows (May 1-10), as well as the VAMP (April 15 – May 15) and Vernalis (October) requirements, which can be relaxed when conditions are dry.

CVP Indices

The Shasta and American River CVP indices included in CalSim-II are used to determine minimum flow requirements in the Sacramento basin. Values of the CVP indices are updated in March and remain invariant over the subsequent 12 months.

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SHASTA INDEX (CVP)

The Shasta Index[11] has 4 levels, where a value of 4 is considered Critically Dry. The Shasta index is used to determine minimum flows in Clear Creek and at Red Bluff. When the index equals 4, reductions are made to Refuge Contracts North of the Delta[12].

AMERICAN RIVER D893 INDEX

The American River D893 Index[13] has 2 levels and is used to determine the H Street minimum flow requirements, specified in Decision 893. Requirements at H Street vary by month and are specified in a lookup table[14].

Miscellaneous Indices

Several stand-alone indices that are applied at various places in the system are also used to set environmental constraints.

THE TRINITY RIVER INDEX

The Trinity River Index[15] has 5 levels: 1 = Wet, 2 = Above Normal, 3 = Below Normal, 4 = Dry, 5 = Critically Dry. The Trinity Index is set in April and held constant throughout the year. The Trinity River Index is used to determine minimum flow requirements in the Trinity River. Requirements for the Trinity River vary by both month and are specified in a lookup table[16].

EIGHT RIVER INDEX

The Eight River Index[17] is a table of pre-calculated, invariant numbers derived from analysis of historic data. The Eight River Index is used to define Minimum Required Delta Outflow requirements in January.

> The most fundamental observation that can be made based on the information presented in the preceding section is that some environmental standards are set based on perfect foresight about the values assigned to water year indices. This assumption can influence the operational logic of the model. Understanding how this operational logic ignores the risk of operating for dynamic environmental objectives is critical to the application of the full environmental compliance and environmentally preferred standards to the performance of CalSim-II.

The Influence of Water Year Indices on the Definition of Risk Tolerance

The most fundamental observation that can be made based on the information presented in the preceding section is that some environmental standards are set based on perfect

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[14] ...\Run\Lookup\HSt_base.table
[15] ...\Run\Lookup\wytypes.table
[16] ...\Run\Lookup\Trintymin.table
[17] ...\Run\Lookup\eightriver.table

foresight about the values assigned to water year indices. This assumption can influence the operational logic of the model. Understanding how this operational logic ignores the risk of operating for dynamic environmental objectives is critical to the application of the full environmental compliance and environmentally preferred standards to the performance of CalSim-II. The easiest way to explain how risk management for the environment could be improved is to illustrate how CalSim-II approaches risk management in promising water deliveries.

CalSim-II relies upon a series of curves to manage uncertainty in promising water to users throughout California: generally these curves define risk tolerance. Specifically, these curves illustrate the ability to promise water deliveries given a specific water year outlook (not to be confused with the water year indices). While the treatment of risk tolerance varies somewhat between the CVP and SWP systems, the procedure used in the CVP portion of the model is illustrative. CVP water allocations (i.e. monthly varying delivery promises) are set by the Water Supply Index-Demand Index (WSI-DI) curve, Figure 1. Here the promised CVP delivery (embedded in the Demand Index) is determined by the specific water year outlook (determined by the Water Supply Index). Unlike the water year indices, the water supply index (WSI) is calculated every month as the sum of storages *plus* an imperfect forecast of inflows.

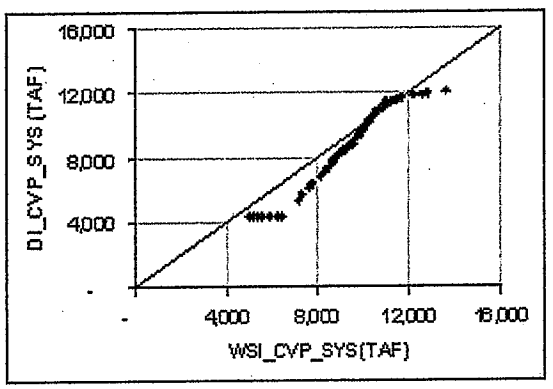

Figure 1 – WSI-DI Curve for CVP water allocations

Three interesting observations emerge from Figure 1. First, at very high levels of water supply the corresponding demand flattens out. This is associated with the fact that the system demand is not unlimited and that above a certain water supply threshold, all water demand can be satisfied. Second, at very low water supply values, the demand index is also flat. This corresponds to the hard water demand that will exist even in the driest conditions. Finally, intermediate to these two tails, an increase in water supply translates into an increase in the water demand that can be satisfied. At high water supply levels all of the available supply is allocated to meet demand. As the water supply decreases, however, the WSI-DI curve falls below the 1:1 line suggesting that a smaller percentage of the available supply is made available to meet demand. This is the first part of the CalSim-II's risk tolerance definition: when conditions are dry, caution is taken in promising water to meet demand.

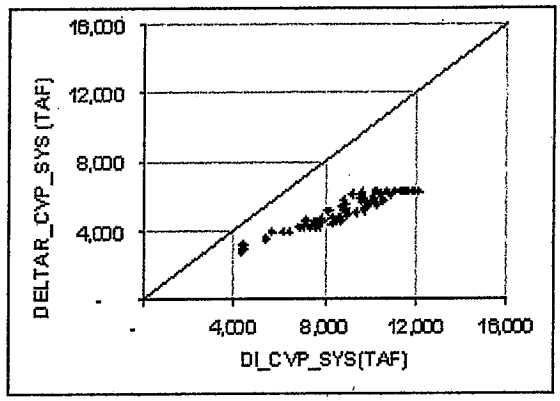

Figure 2 – Del-Car Curve for CVP water allocations

The Demand Index, however, is the sum of both delivery and carry-over storage demands. A second step in determining the CVP water allocations in CalSim-II involves partitioning of the available water between CVP contractors and storage in CVP reservoirs. The Delivery-Carry Over (DelCar) Curve, Figure 2, accomplishes this. Note that the curve has a high-end tail similar to the WSI-DI curve, which occurs during full contract deliveries to CVP contractors. As the Demand Index decreases in value, a smaller percentage of the available supply is committed to carry over storage relative to the amount that is delivered to meet current water demand. This is the second component of the risk tolerance included in CalSim-II: as conditions get dry, a larger percentage of available supply is used to meet current demands in the hope that future inflows will restore reservoir storage levels. Notice that at a DI value of roughly 4000 TAF, the nearly all of the water available to meet demand, is being delivered to satisfy current needs.

At this point the reader is probably wondering how the shape of these two curves are established. In other words, how is the acceptable level of risk tolerance defined? The answer is that some trial and error takes place to train the WSI-DI and DelCar curves. Before describing this process, however, a short digression is made to respond to the other question likely on the mind of the reader, namely how are forecasts of reservoir inflows used to define WSI?

CalSim-II makes a series of annual water allocation decisions starting in February of each water year. At that moment, based on an analysis of historic conditions that has been conducted outside of CalSim-II, knowledge of the snow pack above the major reservoirs in a given water year is added to the level of precipitation that, over the ensuing 5 months, has been exceeded 99% of the time in the historic record. A simple regression model developed by the Department of Water Resources is then used to translate the existing snow pack and anticipated rainfall into a predicted level of reservoir inflow that is added to the water already in reservoir storage to yield the Water Supply Index shown on the x-axis of Figure 1. Unless there is an unusually large snow pack in place in February, by anticipating such a low level of precipitation, CalSim-II likely forces the value of WSI to fall relatively low on the x-axis of Figure 1. This translates to a relatively modest commitment to satisfy demand that may results in delivery cuts being set by the allocation logic relative to full contract amounts.

The forecasted reservoir inflow is updated during the March, April and May time-steps using the process described above and historic information on the available snow pack and future precipitation at the levels exceeded 90, 75 and 50% of the time, respectively. These updated reservoir inflow forecasts are combined with the simulated level of reservoir storage to define a new value of WSI that is translated to a commitment to deliver water to satisfy current needs. If this leads to a higher level of delivery, then the cut logic invoked during an earlier time step is relaxed. By June, the value of WSI is considered fixed for the current water year.

One final comment is warranted. If the situation worsens as the process is implemented, for example if warm late winter temperatures deplete the snow-pack, forcing releases from reservoirs to comply with flood control obligations, and the actual precipitation is less than that which was forecast, the allocation logic will not reduce the quantity of deliveries defined during a previous time step, and end-of-year carry-over storage will be reduced as a consequence.

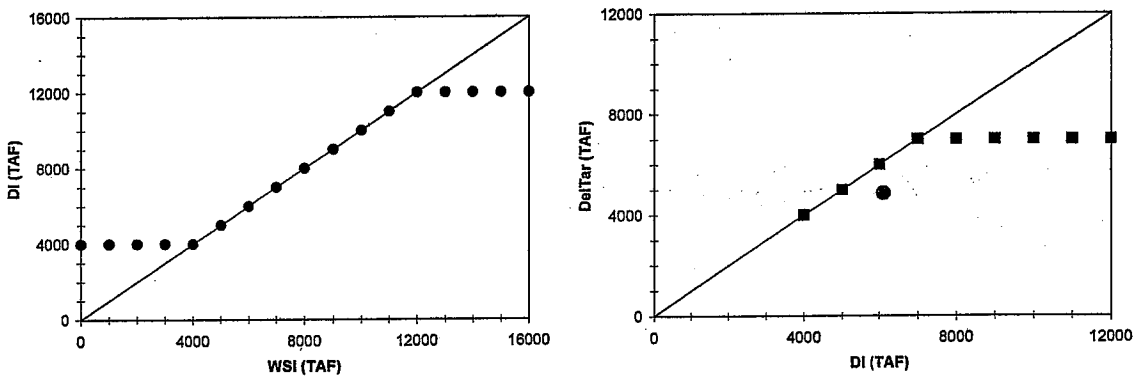

Figure 3 – Stylized Representation of Maximum Risk Tolerance

As alluded to above, the WSI values arrived at by implementing this iterative process drive the use of the WSI-DI and DelCar Curves shown in Figures 1 and 2. This brings us back to the question of how the shape of the curves is established. The most aggressive possible operational strategy for providing water to users would be to use all of the available supply to meet current needs. This posture is stylized in Figure 3. As in Figures 1 and 2, the tails at the upper and lower values of WSI and DI have been preserved. At intermediate values, however, all available water is used to satisfy the current need for water deliveries as both the WSI-DI and DelCar Curves follow the 1:1 line. This posture, however, presumes that the system is completely unconstrained in its ability to deliver all available water to demands throughout the Central Valley. Four primary constraints act to prevent this aggressive delivery policy.

1. There is uncertainly associated with the forecast value of WSI;
2. The actual physical capacity of installed infrastructure can limit water deliveries;
3. Carry-over storage is critical to meeting water management objectives in future years; and most importantly from the perspective of this review
4. Constraints related to environmental regulations may limit the delivery of water.

These factors could, therefore, conspire to create a situation whereby the actual deliveries to demands throughout the system would be somewhat less than promised (e.g. the circle on the right-hand graph in Figure 3). This failure to deliver promised water is in essence a "broken promise" to contractors, and was deemed unacceptable to the CalSim-II development team. To avoid this situation, the WSI-DI and DelCar Curves were developed to add prudence to the interpretation of how much water is available, and what fraction thereof is deliverable. Obviously, this is a departure from the most aggressive posture (Figure 3) toward the aversion to promise deliveries that ultimately cannot be made as expressed in Figure 1 and Figure 2.

The most fundamental observation from the review of CalSim-II is that the environmental constraints used to train the WSI-DI and DelCar Curves were based on a number of *a priori* assumptions, including perfect foresight associated with the use of water year indices. Our thoughts on the implications of the assumptions are found in the section discussing proposed work plans to meet the Full Compliance and Environmentally Preferred standards. The overall implications of perfect foresight should also be kept in mind as the reader reviews the details of specific environmental standards found in the following section.

Detailed Analysis of Specific Environmental Regulations

As mentioned earlier, CalSim-II includes representations of numerous environmental standards, more in fact than could be examined given the time and resources available to this review process. Starting from the input matrix that is typically used to describe a CalSim-II model formulation, the following table identifies the portions of CalSim-II Common Assumptions Baseline code that we evaluated as part of this study.

Regulatory Standards
Trinity River
Upper Sacramento River
Feather River
American River
Stanislaus River
Sacramento-San Joaquin Delta
Operations Criteria
Subsystem
• Stanislaus River
System Wide
• CVP Water Allocation
• CVPIA 3406(b)(2)

Before launching into the specific details of particular environmental regulations, it is probably worthwhile to present the logic of model cycles and model steps used in CalSim-II. CalSim-II is, in fact, run iteratively (recall the discussion of cycles) with different assumptions being applied to the model during each iteration. The pattern of iteration is shown in Figure 4.

Beginning in October, the first month of a water year, CalSim-II executes a series of model cycles that iteratively add objectives to the system. The first cycle involves meeting delivery requirements on the east side of the San Joaquin Valley. During the second cycle, base operations are checked against certain water quality standards for the San Joaquin River, and additional releases are made if required and possible. In the third cycle, it attempts to satisfy pulse flow requirements for the San Joaquin River and its tributaries. The fourth cycle checks that the San Joaquin River water quality standards are still being met after the addition of the pulse flows, and it makes adjustments if needed and feasible. The fifth and final cycle for the San Joaquin River applies specific objectives such as the Vernalis Adaptive Management Plan and the Stanislaus River dissolved oxygen standards.

At the end of the fifth cycle, the CalSim-II representation of San Joaquin River inflows to the Delta is established for the month. The next two cycles add in all of the model logic related to the water management in the Sacramento River, the Delta and the Export zone. Once releases under all seven cycles are calculated, CalSim-II moves on to the next month of the water year. The set of seven calculation cycles continues until calculations for the final month of the water year, September, are completed.

At this point, it is important to introduce and define a new term: "steps." Steps represent the final, monthly set of releases for a 12 month water year. CalSim-II utilizes several

steps before finalizing monthly releases made throughout each water year. Each step in CalSim-II corresponds with a particular water resource policy benchmark. CalSim-II is required to calculate releases under multiple policy regimes because policies (such as the (b)(2)) manage and account for water deliveries relative to releases that *might* have been made under prior regulatory environments.

The first CalSim-II step, referred to as D-1485, calculates releases that would have been made under the regulatory environment pre-dating the enactment of the Water Quality Control Plan. Older regulatory environments can present opportunities to deliver water that are greater than they would be under present conditions. These 'false' opportunities are not reported as the actual availability of water, but are instead used to measure changes in delivery as a result of changes in regulatory policy.

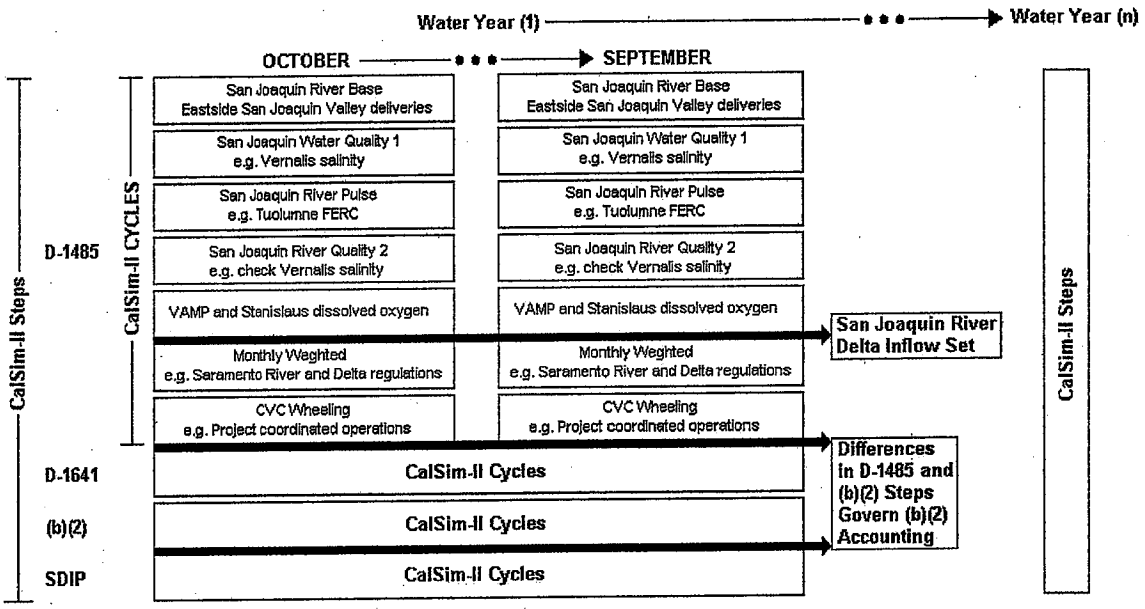

Figure 4 – CalSim-II model cycles and steps

The second CalSim-II model step assumes that the Water Quality Control Plan is in place, which increasingly constrains the ability to deliver water. Any reduction is accounted for as the cost of implementing the Water Quality Control Plan. The next model step assumes that the (b)(2) provisions of the CVPIA require between 600 and 800 TAF of CVP water to be rededicated to environmental objectives. During this step, in completing the seven cycles for the 12 months of a water year, CalSim-II invokes a series of actions that can provide the extra water relative to that which was used for environmental purposes in the D-1485 step. This implies that additional environmental water uses associated with implementation of the Water Quality Control Plan are counted against the (b)(2) obligation. Once all of the environmental considerations are addressed, CalSim-II completes a final step to resolve management considerations related to the adoption of the South Delta Improvement Plan. Only after all cycles and steps are completed for a given 12 month water year does CalSim-II move on to calculations for the following water year, beginning with October.

The implications of this pattern of iteration employed by CalSim-II should be kept in mind as the reader reviews details of specific environmental regulations presented below.

CVPIA 3406(b)(2) Accounting

Section 3406(b)(2) of the Central Valley Project Improvement Act states that the Central Valley Project will:

> "dedicate and manage annually 800,000 acre-feet of Central Valley Project yield for the primary purpose of implementing the fish, wildlife, and habitat restoration purposes and measures authorized by this title; to assist the State of California in its efforts to protect the waters of the San Francisco Bay/Sacramento-San Joaquin Delta Estuary; and to help to meet such obligations as may be legally imposed upon the Central Valley Project under State or Federal law following the date of enactment of this title, including but not limited to additional obligations under the Federal Endangered Species Act."

This prescription has, since the passage of CVPIA, been the focus of protracted legal and administrative wrangling. The key questions relate to whether or not the 800 TAF dedication to restoration efforts applies in all years and what actions taken in the operation of the CVP system can be considered as acceptable contributions to the (b)(2) account. In May 2003 the Department of the Interior issued what are considered to be the current rules for interpreting Congressional intent. These are summarized below.

A. Accounting Period
The accounting period for determining the use of the annual (b)(2) allocation will be October 1 through September 30.

B. Accounting Methodology
The appropriate accounting methodology for the dedication and management of (b)(2) water is based upon how and where the water is used. Interior's new methodology for accounting for (b)(2) will involve only two measurement methods, or metrics, to account for how the water is managed under (b)(2). The two metrics used will be upstream releases and Delta exports.

1. Upstream Actions – October 1 through September 30

   a. Accounting Methodology
   Upstream fishery actions from October 1 through September 30 will be accounted as the increase in releases from upstream reservoirs with the fishery actions, compared to releases from the reservoirs[18] that would have resulted from baseline CVP operations[19] during the same period without the fishery actions. The calculation of the increase in release with the fishery measures will be based on daily changes in releases resulting from the (b)(2) measures prescribed by the Fish & Wildlife Service (Service), accumulated over the period.

   b. Upstream Releases may Flow through Delta
   If specified by Interior, based on a written assessment of biological benefits to the fishery from the Service, steps will be pursued under California law to allow upstream releases to flow through the Delta. Upstream releases specified to flow through the Delta would be accounted for solely under this provision, and not as Delta actions.

2. Delta Actions that affect Exports – October 1 through September 30

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[18] Releases from Trinity Reservoir for Trinity River flows pursuant to 3406(b)(23) of the CVPIA are excluded from the accounting under this provision. Releases to the river from Whiskeytown Dam, Keswick Dam, Nimbus Dam and Goodwin Dam comprise the basis for this metric.

[19] Interior is currently using the pre-1992 base CVP operations with D-1485 water quality obligations as the baseline CVP operation. The pre-1992 baseline includes the 1992 Winter Run Chinook Salmon Biological Opinion and other licenses and permits as construed at that time.

a. Accounting Methodology

Delta actions that affect exports will be accounted throughout the water year as the reduction in exports from the Delta resulting from the prescribed fishery actions. Any export reductions prescribed by the Service below the baseline operation will be accounted as (b)(2) actions. The calculation of decrease in Delta exports with the fishery measures will be based on daily changes in Delta exports with the fishery measures will be based on daily changes in Delta exports resulting from the (b)(2) measures prescribed by the Service, accumulated over the period.

b. Limitation on Delta Actions – February 1 through August 31

During the period February 1 through August 31 (the "low point" for CVP storage in San Luis Reservoir), (b)(2) prescriptions for export reductions will be limited to a maximum of 640,000 acre-feet (80 percent of 800,000 acre-feet of (b)(2) water). This maximum amount will be reduced up-to 80 percent when the overall water available to (b)(2) is reduced in Dry and Critical water years.

The Department of the Interior decision continues to state, "... for the purposes of classifying the water year type and developing operation plans, the 90-percent exceedence hydrology will be used."

Translating these legislative and administrative guidelines into CalSim-II model logic is a complicated endeavor. Two observations regarding the manner in which this was accomplished are particularly relevant to this environmental review. First, in spite of the suggestion that some notion of uncertainty be applied to the determination of water year type, CalSim-II employs perfect foresight in determining the amount of water that must be dedicated to (b)(2) actions. Based on the 40-30-30 Sacramento River Index which is read into CalSim-II during the February time step, CalSim-II sets the size of the (b)(2) account for the entire water year at the levels shown in Table 1.

CalSim-II employs perfect foresight in determining the amount of water that must be dedicated to (b)(2) actions.

Table 1 – Annual (b)(2) requirements based on Sacramento River water year type

Sacramento River Water Year Type	(b)(2) Requirement (TAF)
Wet	800
Above Normal	800
Normal	800
Below Normal	700
Critically Dry	600

The second pertinent observation is that CalSim-II employs the simulated operation of the system following the D-1485 step (see Figure 4, above) as a baseline against which additional ecosystem restoration actions called for under (b)(2) are measured. This implies that all CVP actions related to implementation of the D-1641 Water Quality Control Plan are considered to be acceptable charges against the (b)(2) account. This belies the fact that water quality actions can have little direct ecosystem benefit. These

observations will be taken up again the discussion of the full environmental compliance and environmentally preferred work plans. For the moment, the remainder of this sections deals with actions taken during the CalSim-II (b)(2) step in order to satisfy (b)(2) obligations.

> This implies that all CVP actions related to implementation of the D-1641 Water Quality Control Plan are considered to be acceptable charges against the (b)(2) account. This belies the fact that water quality actions can have little direct ecosystem benefit.

As stated in the Department of the Interior guideline, either increases in releases from CVP regulating reservoirs (Whiskeytown, Keswick, Nimbus, and Goodwin), or decreases in CVP Delta exports relative to a pre-1992 baseline, can be considered to constitute contributions against the (b)(2) obligations. These are described in the standing interpretations, and in CalSim-II, as the Release Metric and the Export Metric. In operation, both are calculated daily. In CalSim-II, the release metric is calculated as the **increase** in total end-of-month releases from CVP reservoirs finalized in the (b)(2) step, relative to the simulated end-of-month releases from CVP reservoirs in the D-1485 step. In the event that the (b)(2) step reduces outflows from CVP reservoirs (relative to D-1485), the (b)(2) account is not credited.

Similarly, the Release Metric is defined as the reduction in end-of-month CVP Delta exports for the (b)(2) step, relative to the D-1485 step. Increased exports (relative to D-1485) are not credited to the (b)(2) account, and the total possible charge to the Release Metric is limited to a fraction of the (b)(2) account. Generally, one of three actions results in a charge to the Release Metric. 1) Changes to the Delta salinity standards between the (b)(2) and D-1485 steps could result in a reduction to exports, 2) exports could be curtailed in the months in April and May as part of the Vernalis Adaptive Management Plan (VAMP), or 3) exports could be curtailed in June in order to bring the (b)(2) account into compliance with the target ecosystem budget.

Table 2 - April and May VAMP export cuts for (b)(2)

Flow at Vernalis (cfs)	CVP Delta Export Restrictions		
	April 1 – 14	April 15 – May 15	May 16 – 31
< 5700	17.5% Inflow	750 CFS	3000 CFS
5700 – 8600	17.5% Inflow	Alternate 750 CFS and 1500 CFS	3000 CFS
> 8600	17.5% Inflow	25% Flow at Vernalis	3000 CFS

VAMP export restrictions from April 1 to May 31 are always activated for (b)(2) accounting purposes (Table 2). The (b)(2) export restrictions apply to CVP Delta exports from Tracy and Banks. During the first non-pulse period, April 1-14, total Delta exports from Tracy and Banks are limited to 35% of Delta inflow[20], with the CVP and the SWP

[20] The sum of Sacramento River flows at Hood, Yolo Bypass return flows, San Joaquin River flows at Vernalis, Mokelumne River, Calaveras River, and Marsh Creek inflows to the Delta.

each being apportioned 50% of the water. During the April 15 – May 15 pulse period, CVP Delta exports are restricted to 750 cfs if the VAMP requirement is less than 5700 cfs. If the VAMP requirement is greater than 5700 cfs then CVP delta exports are restricted to either 750 or 1500 cfs, depending upon the previous year's VAMP restriction. This export restriction alternates between years. Maximum CVP exports are increased to 25% of flows at Vernalis if they are greater than 8600 cfs. In the second non-pulse period, May 16-30, CVP Delta exports are restricted to 3000 cfs. If extending the pulse period restrictions through the end of May is more than what is needed to satisfy (b)(2) requirements then the pumping restrictions for May 16-31 will be adjusted to a level that brings the CVP into compliance with its (b)(2) obligations.

CVP delta exports in June are always restricted to a maximum of 3000 cfs. If there are remaining (b)(2) costs that are not met by projected WQCP actions then CVP pumping at Tracy and Banks will be curtailed. June CVP delta pumping can be reduced from the 3000 cfs standard, but cannot be reduced below the level of export pumping simulated during May. In addition, pulse period pumping restrictions can be applied for the first 7 days in June and increased to 3000 cfs for the remaining 23 days of the month. If extending the pulse period restriction through the first week of June exceeds the amount needed to satisfy (b)(2) requirements then June pumping restrictions will be adjusted to a level that brings the CVP into compliance with its (b)(2) obligations.

Keep in mind as you read the following sections and work plans that modeling (b)(2) correctly requires both correct representation and correct comparison. Representation is more or less an issue of capturing the regulated policy, e.g. there are 800 TAF for disbursement. Comparison is an issue of appropriately capturing the accounting baseline, and charging specific accounts at the appropriate point within the myriad of cycles and steps being performed to calculate operations.

A comment: CalSim-II contains an impressive bulk of code devoted specifically to the accounting of (b)(2) water. Literally, over half of the current model could be eliminated if the (b)(2) account were not being tracked. This demonstrates the power and flexibility of CalSim-II's environment for adopting incremental accounting regulations such as (b)(2). Conversely, this makes an enormous statement about the magnitude of effort required to track "packets" of water running through the Central Valley, as if water releases were so many parcels being ferried through a factory on conveyor belts. While tracking incremental quantities may be appropriate for contracted deliveries, it is an ill-conceived starting point for protecting environmental services because they depend more upon the 'state' of the system than upon raw quantities. There is a need to move away from incremental policies such as the (b)(2) toward dynamic water management decision making that is driven by targeted responses to current environmental conditions. This suggestion also speaks directly to a primary issue that stakeholders have with models: transparency. Quite simply, less complex accounting procedures require less code. Less code makes water resource

There is a need to move away from incremental policies such as the (b)(2) toward dynamic water management decision making that is driven by targeted responses to current environmental conditions.

models simpler to explain, to track and to understand: thereby making the dialogue over alternatives more accessible to stakeholders. While the authors harbor no great illusions about California's water resource system and regulatory environment getting simplified, we suggest it as a practical rule of thumb for future policy directions.

Trinity Operations

CalSim-II models releases of water from storage in the Trinity System along two arcs, marked in Figure 5 as C100 (Trinity River) and D100 (Clear Creek Tunnel). The logic dividing flows between the Trinity River releases and diversion towards the Sacramento River are relatively straightforward.

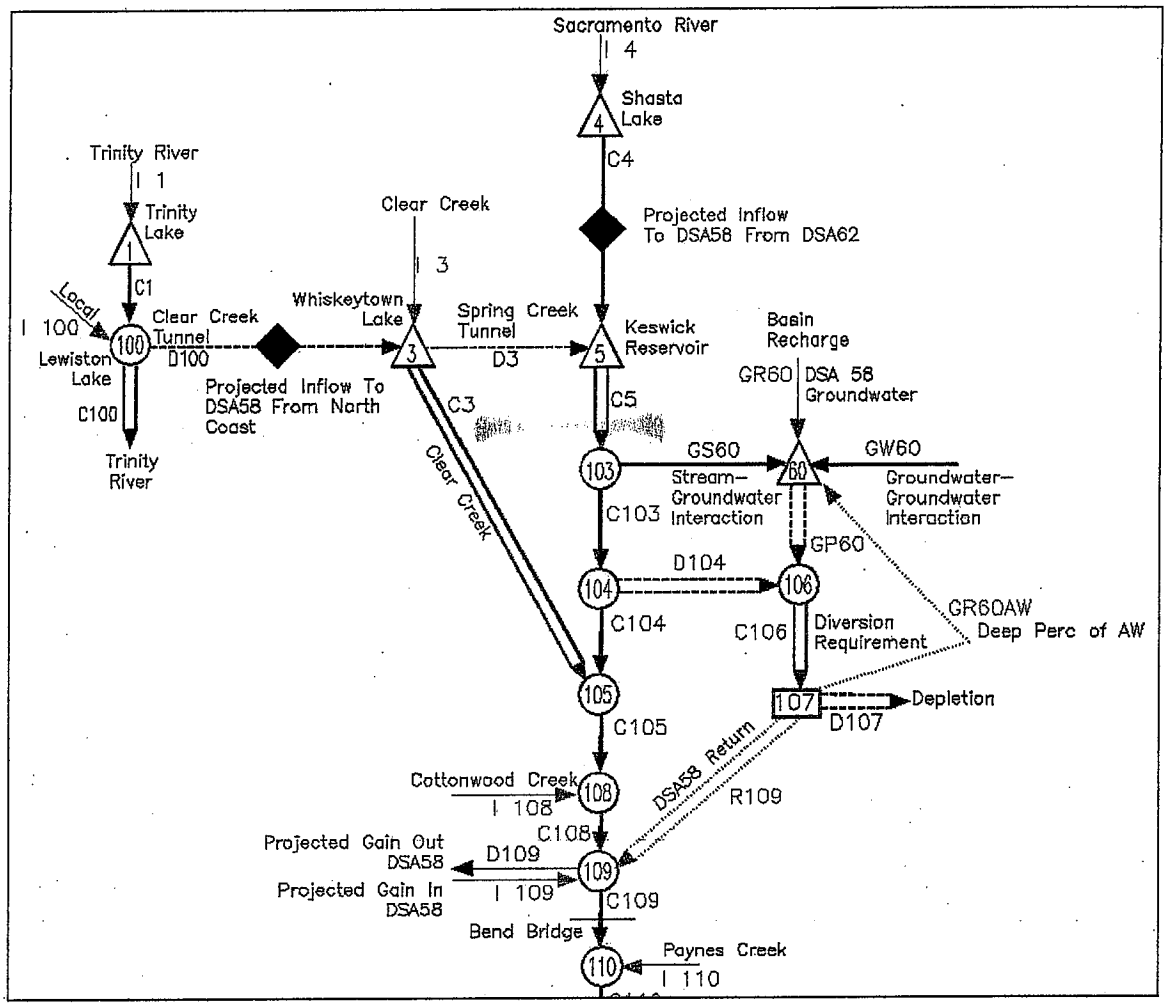

Figure 5 - Trinity Storage and Releases, represented on the CalSim-II schematic as reservoir 1 and arcs C100 (Trinity River) and D100 (Clear Creek Tunnel)

The Trinity River water year index determines the release schedule for the Trinity River[21]. The release schedule is referenced from a lookup table (Table 3), and is the same for each CalSim-II step.[22] Notice that there are significant differences between required releases to the Lower Trinity depending on the water year index, particularly during the late spring and early summer months. This is the kind of difference that has implications for the manner in which risk tolerance is established in CalSim-II, as discussed in the previous section.

[21] ...\common\NorthOfDelta\Trinity\Trinitymin.wresl
[22] ...\Run\Lookup\Trinitymin.table

Table 3 – Trinity River minimum flow requirements (cfs), set by the Trinity water year index

Month	Trinity River Water Year Index				
	Wet (1)	Above Normal (2)	Below Normal (3)	Dry (4)	Critical (5)
October	373	373	373	373	373
November	300	300	300	300	300
December	300	300	300	300	300
January	300	300	300	300	300
February	300	300	300	300	300
March	300	300	300	300	300
April	427	460	493	540	600
May	4570	4709	4189	2924	1498
June	4626	2526	2120	783	783
July	1102	1102	1102	450	450
August	450	450	450	450	450
September	450	450	450	450	450

Trinity river transfers to the Sacramento River basin are made through the 3300 cfs Spring Creek tunnel into Whiskeytown Reservoir. The transfer goal is set relative to the storage levels in Lake Shasta and in reservoirs on the Trinity River. In both cases, Storage Level 1 corresponds to the lowest storage zone, in which case a reservoir is extremely drawn down. At the highest reservoir storage levels, Level 5 for the Trinity reservoirs and Level 6 at Lake Shasta, reservoirs are so full that they are spilling water. Table 2 shows the assigned relationship between the Trinity to Sacramento transfer targets and the storage levels in the two reservoirs.[23] These transfer values can be exceeded when, for instance, Trinity is spilling and the "excess flows" in the Trinity River are used to augment CVP storages or to meet Delta outflow objectives. This is important because when the Trinity River transfers are increased between the D1485 step and the (b)(2) step, the transfer of this "excess flow" is accounted for as a charge against the (b)(2) obligations. As a result the model may be able to avoid clearly beneficial environmental actions called for under (b)(2) during the spring months.

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[23] ...\Run\Lookup\trinity_import.table

Table 4 – Trinity River Diversions through Clear Creek Tunnel (cfs)

Trinity Level	Shasta Level	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1	1	0	0	0	0	0	0	0	0	250	250	250	250
1	2	0	0	0	0	0	0	0	0	250	250	250	250
1	3	0	0	0	0	0	0	0	0	250	250	250	250
1	4	0	0	0	0	0	0	0	0	250	250	250	250
1	5	0	0	0	0	0	0	0	0	250	250	250	250
1	6	0	0	0	0	0	0	0	0	0	0	0	0
2	1	250	100	100	100	100	100	100	100	250	1500	1500	1000
2	2	250	100	100	100	100	100	100	100	250	1500	1500	1000
2	3	250	100	100	100	100	100	100	100	250	1250	1250	1000
2	4	250	100	100	100	100	100	100	100	250	1000	1000	750
2	5	250	0	0	0	0	0	0	0	250	750	750	500
2	6	0	0	0	0	0	0	0	0	0	0	0	0
3	1	1250	750	250	250	250	250	250	250	1250	2500	2500	1750
3	2	1250	750	250	250	250	250	250	250	1250	2500	2500	1750
3	3	1000	500	250	250	250	250	250	250	1000	2250	2250	1500
3	4	750	500	250	250	250	250	250	250	750	1750	1750	1500
3	5	750	250	100	100	100	100	100	100	750	1500	1500	1000
3	6	0	0	0	0	0	0	0	0	0	0	0	0
4	1	1750	1000	250	250	250	250	250	250	1750	3250	3250	3250
4	2	1750	1000	250	250	250	250	250	250	1750	3250	3250	3250
4	3	1500	750	250	250	250	250	250	250	1500	2500	2500	2500
4	4	1250	500	250	250	250	250	250	250	1250	2000	2000	2000
4	5	750	500	100	100	100	100	100	100	750	1500	1500	1500
4	6	0	0	0	0	0	0	0	0	0	0	0	0
5	1	3250	3000	1000	250	250	250	250	250	3000	3250	3250	3250
5	2	3250	3000	1000	250	250	250	250	250	3000	3250	3250	3250
5	3	2750	2500	750	250	250	250	250	250	2500	3000	3000	3000
5	4	2500	1750	500	250	250	250	250	250	1750	2750	2750	2750
5	5	1500	1500	500	100	100	100	100	100	1500	1500	1500	1500
5	6	0	0	0	0	0	0	0	0	0	0	0	0

Shasta/Keswick Downstream Releases

CalSim-II models releases of water from storage in the Shasta/Keswick along two arcs, marked in the Figure 6 as C4 (Shasta releases) and C5 (Keswick releases). Model logic associated with these arcs account for minimum flow requirements in the Sacramento River.

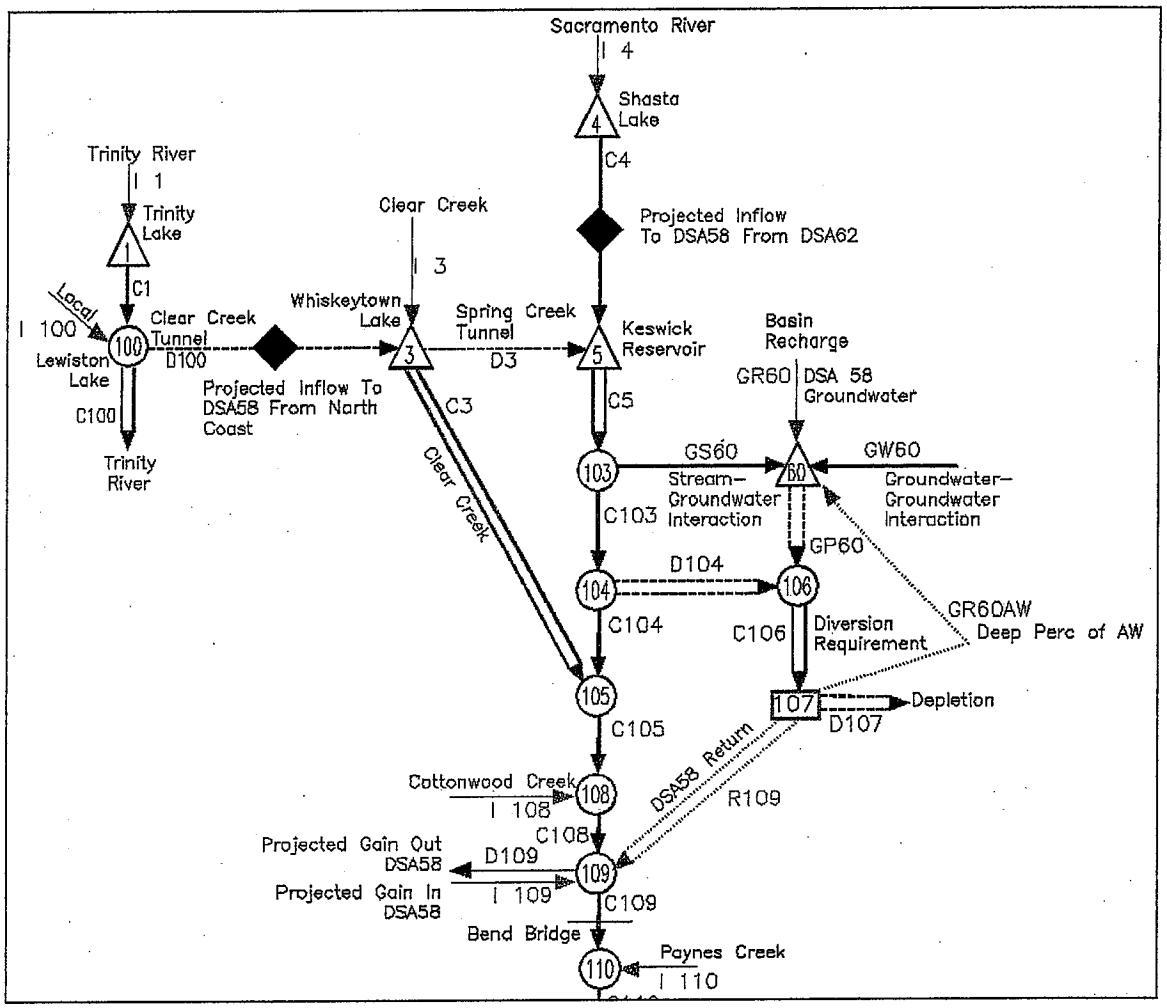

Figure 6 - Shasta/Keswick Storage and Releases, represented on the CalSim-II schematic through reservoirs 4 and 5 and arcs C4 and C5

The minimum flow requirement has three parts: (1) the Keswick Temperature Requirement, (2) the Stability Flow Requirement, and (3) the AFRP requirement. The Keswick Temperature Requirement is based upon the storage in Lake Shasta at the end of September. These values are taken from a look-up table[24] and applied continuously throughout the year (Table 5). Temperature requirements are applied in all CalSim-II model steps (D1485 through SDIP).

[24] ... \Run\Lookup\keswick_tempcntrl.table

The Stability Flow requirement exists to maintain the stability of the downstream levee systems against sloughing that could occur as a result of rapid, dramatic declines in river levels. If outflows from Shasta fall below a threshold, the current month's reservoir release must be maintained at a certain fraction of the previous month's reservoir release to sustain the structural integrity of the earthen riverbanks. The thresholds and fractions associated with this regulation are given in Table 6[25], and the Stability Requirement is only invoked when the previous month's flows are below the stability threshold. Stability requirements are applied only in the (b)(2) step and can result in charges to the (b)(2) account.

Table 5 – Temperature Releases from Shasta Dam (in cfs) corresponding storages

Storage in Shasta (TAF)	Oct	Nov	through	Mar	Apr	May	Jun	Jul	Aug	Sep
0	3,250				3,250	3,250	3,250	3,250	3,250	3,250
2,000	3,250				3,250	3,250	3,250	3,250	3,250	3,250
2,500	3,250				4,000	5,500	5,500	6,000	6,000	4,500
3,250	4,000		3,250		4,250	6,350	7,000	8,500	8,000	5,500
3,750	4,500				4,500	7,000	8,000	9,500	9,000	6,000
4,500	5,000				5,000	8,000	9,000	11,000	10,000	6,500
>4,500	5,000				5,000	8,000	9,000	11,000	10,000	6,500

Table 6 – Stability of Flow requirements for Shasta Dam, coded to represent FWS management of b2 under the May 2003 Department of Interior (b)(2) Decision

	Previous month's release from Shasta-Keswick (cfs)	Required Fraction of previous month's flow to maintain in current month
November	<6,000	65%
December	<4,500	90%
January	<4,500	80%
February	<4,500	80%
March	<4,500	80%

The Anadromous Fish Restoration Plan (AFRP) flow requirements for the Sacramento River below Shasta and Keswick are based on the previous month's Shasta storage or, between March and September, upon storage plus a forecast of inflows[26] (Table 7). These forecasts are based on 99%, 90%, 75%, and 50% exceedence probabilities for February, March, April, and May through September, respectively. AFRP requirements are applied in the (b)(2) step and can result in charges to the (b)(2) account.

Between the temperature, stability, and AFRP requirements the maximum requirement is not always applied. In conditions when large (b)(2) allocations have been made by the end of January, the AFRP requirement will be relaxed, and the next highest of the temperature and stability flow requirements will be applied[27]. Table 8 explains this

[25] ...\(b)(2)\Run\Lookup\SacStability.table
[26] ...\(b)(2)\Run\Lookup\sacramento_runoff_forecast.table
[27] ...\(b)(2)\Run\(b)(2)Actions\(b)(2)Action1.wresl

decision logic. The bottom two rows in Table 8 refer to "Expected AFRP Costs in January." This value is calculated as the sum of previous costs plus full AFRP flow requirements in January from Whiskeytown, Shasta/Keswick and Folsom/Nimbus. As indicated in the table, requirements that result in (b)(2) costs in excess of 200 TAF by the end of January will be relaxed. This relaxation is performed to conserve (b)(2) water through the spring.

Table 7 – AFRP flow requirements are specified (in cfs) by the storage in Shasta (TAF). Values marked "" were not tabulated, and are determined through linear interpolation**

Shasta Storage (TAF)	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
0	3250	3250	3250	3250	3250	3250	3250	3250	3250	3250	3250	4500
1500	**	**	**	3500	**	**	**	3250	3250	3250	3250	**
1750	**	**	**	**	3500	**	**	3250	3250	3250	3250	**
2000	**	**	**	3750	**	3500	3500	3250	3250	3250	3250	6000
2200	3500	3500	3500	**	3750	**	**	3250	3250	3250	3250	6000
2300	3750	3750	3750	**	**	**	**	3250	3250	3250	3250	6000
2400	4000	4000	4000	**	**	3750	3750	3250	3250	3250	3250	6000
2500	4250	4250	4250	**	**	**	**	3250	3250	3250	3250	6000
2600	4500	4500	4500	4000	**	**	**	3250	3250	3250	3250	6000
2700	4750	4750	4750	4250	4000	**	**	3250	3250	3250	3250	6000
2800	5000	5000	5000	4500	4250	**	**	3250	3250	3250	3250	6000
2900	5250	5250	5250	4750	4500	**	**	3250	3250	3250	3250	6000
3000	5500	5500	5500	5000	4750	4000	**	3250	3250	3250	3250	6000
3050	5500	5500	5500	**	**	4250	**	3250	3250	3250	3250	6000
3100	5500	5500	5500	5250	5000	4500	**	3250	3250	3250	3250	6000
3150	5500	5500	5500	**	**	4750	**	3250	3250	3250	3250	6000
3200	5500	5500	5500	5500	5250	5000	4000	3250	3250	3250	3250	6000
3300	5500	5500	5500	5500	5500	5250	4250	3250	3250	3250	3250	6000
3400	5500	5500	5500	5500	5500	5500	4500	3250	3250	3250	3250	6000
3500	5500	5500	5500	5500	5500	5500	4750	3250	3250	3250	3250	6000
3600	5500	5500	5500	5500	5500	5500	5000	3250	3250	3250	3250	6000
3700	5500	5500	5500	5500	5500	5500	5250	3250	3250	3250	3250	6000
3800	5500	5500	5500	5500	5500	5500	5500	3250	3250	3250	3250	6000
4552	5500	5500	5500	5500	5500	5500	5500	3250	3250	3250	3250	6000

Table 8 – Minimum flow selection matrix, assuming that the Stability Requirement is evoked

Month	(b)(2) Account Condition	Shasta Minimum Flow Requirement
Dec	(b)(2) costs through Nov. >50 TAF	Max between (Temp, Stability), but not above the AFRP requirement
Dec	(b)(2) costs through Nov. <50 TAF	Max (Temp, Stability, AFRP)
Jan	(b)(2) costs through Dec. >150 TAF	Max between (Temp, Stability), but not above the AFRP requirement
Jan	(b)(2) costs through Dec. <150 TAF	Max (Temp, Stability, AFRP)
Jan	(b)(2) costs through Dec. + Expected AFRP Cost in Jan >200 TAF	Max between (Temp, Stability), but not above the AFRP requirement
Jan	(b)(2) costs through Dec. + Expected AFRP Cost in Jan <200 TAF	Max (Temp, Stability, AFRP)

Shasta's storage is treated as part of the larger, integrated Central Valley Project. As such, releases can be made from Shasta in order to fulfill obligations (e.g. delta outflow, instream requirements, export, wheeling, or COA) that are shared among CVP reservoirs. Generally, CalSim-II attempts to keep Shasta, Folsom, and Trinity reservoirs in the same storage zones, thereby balancing the obligations for water with both the capacity of the three dams, and probably the likelihood of being refilled. This balancing, however, is relevant to the 1993 Winter Run Biological Opinion that includes a provision for minimum carryover storage in Lake Shasta of 1.9 MAF at the minimum end-of-September. In CalSim-II, this storage goal is not made explicitly and the fulfillment of the requirement must be judged through an analysis of the output generated at the end of a particular simulation. For the common assumptions baseline, the time-series of simulated September End-of-Month storage is shown in Figure 7.

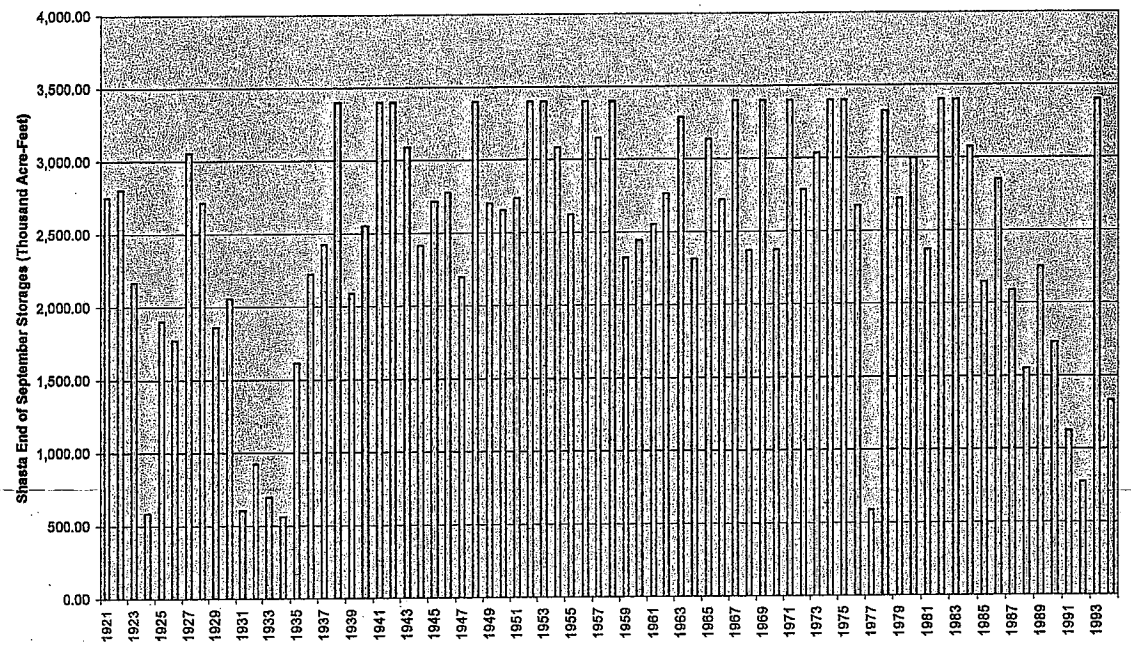

Figure 7 – End of September storages resulting from Baseline (CA_2020D09D_FutureSDIP_2_1) CalSim-II operations

Oroville/Thermalito Downstream Releases

CalSim-II models the combined releases from Oroville and Thermalito along one arc, marked in the Figure 8 as C203. There are three minimum flow requirements imposed on Feather River releases, all of which are expressed in one sub-arc, C203_MIF[28].

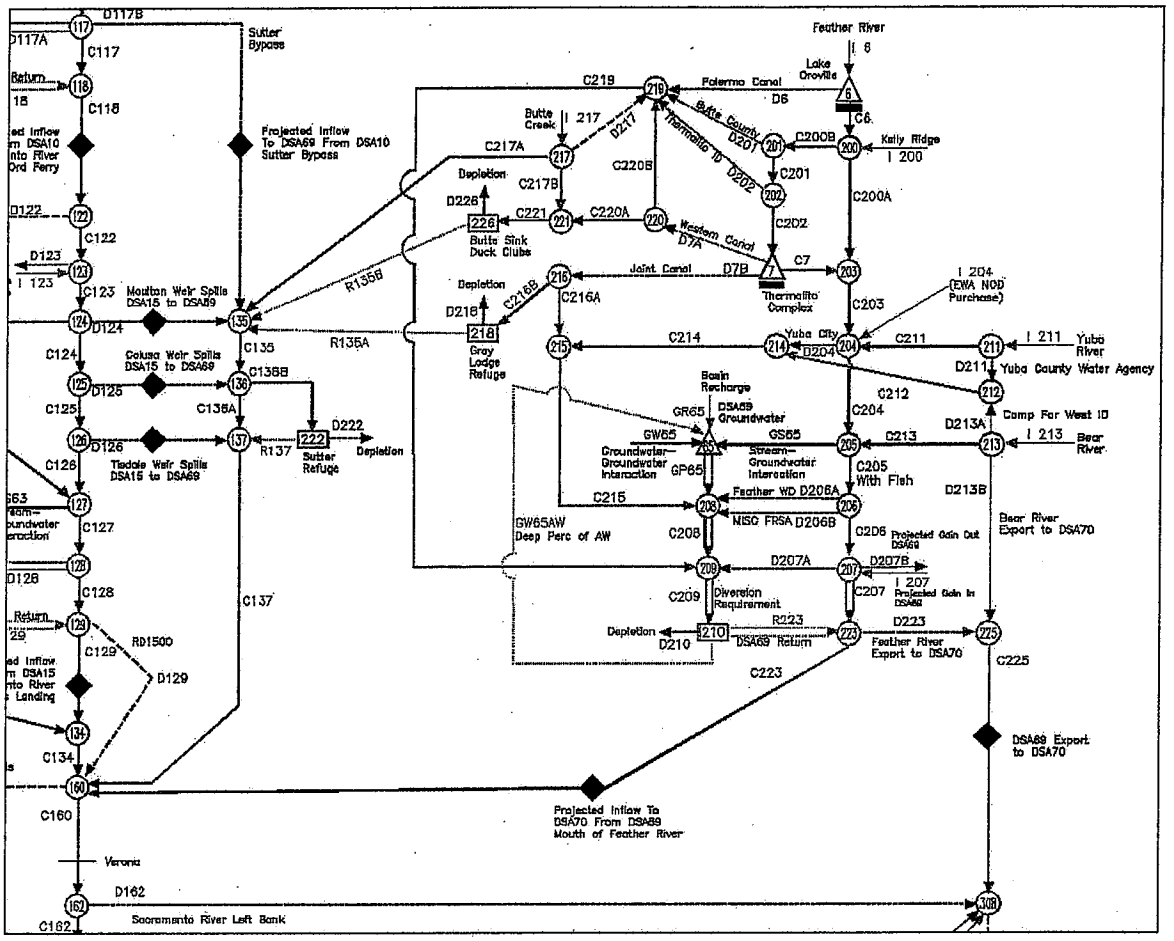

Figure 8 - Oroville/Thermalito Storage and Releases, represented on the CalSim-II schematic through reservoirs 6 and 7 and arc C6, C7 and (as a combined flow) C203

If flows on the Feather River exceed an average of 4,000 cfs in October, or 2,500 cfs in November, then the following months (through March) must maintain at least the previous months flow, minus 500 cfs. The only exception to this requirement is in the event of an October or November flood (expressed as Lake Oroville storage in zone 6), in which case no flow requirements are triggered for the following months. CalSim-II attempts to avoid this minimum flow requirement by placing a heavy penalty on flows above 4,000 cfs in October and 2,500 cfs in November.

There is also a minimum instream flow requirement set for the reach of the Feather River between Thermalito and Verona that varies between 750-1,850 cfs depending on the month and the water year.

[28] ...\common\NorthOfDelta\Feather\feather_special.wresl

Finally, between April and September, Lake Oroville is called upon to provide 2,800 cfs in addition to diversions along the Feather River, shown in the CalSim-II schematic as D7A, D7B, D206A, and D206B. Yuba River inflows count toward this requirement. Additionally, the instream flow requirement here is constrained such that the sum of the diversions and instream flow requirement will not exceed the monthly inflow to Oroville Dam. The implication is that maintaining reservoir levels is a higher priority than the satisfaction of downstream environmental flows.

Folsom/Nimbus Downstream Releases

CalSim-II models releases from Folsom and Nimbus along two arcs, marked in Figure 9 as C8 and C9. The Nimbus release arc is divided into three sub-arcs, to assist in accounting for release requirements.

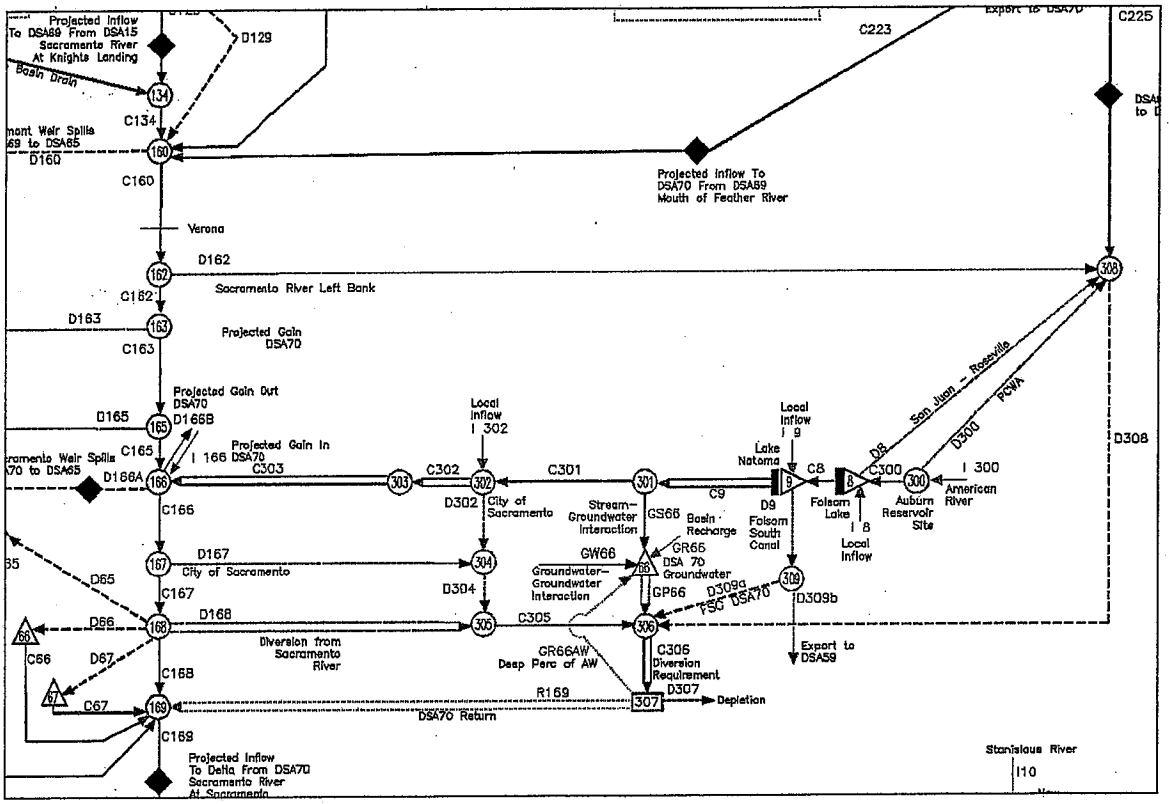

Figure 9 - Folsom/Nimbus Storage and Releases, represented on the CalSim-II schematic through reservoirs 8 and 9 and arc C8 and C9

The historic flow requirement at Folsom is based upon "modified D-1400" requirements, as they were modeled within the PROSIM environment[29]. This flow requirement calls for distinct downstream release actions depending on whether the Folsom storage is above or below 200 TAF. If storage is above 200 TAF, CalSim-II bases minimum flow requirements on either storage in Folsom (October – February) or storage plus a forecast of inflows until the end of the water yeas in September (March – September)[30]. Forecasts are based on 99%, 90%, 75% and 50% exceedence probabilities for February, March, April and May through September, respectively. Minimum flows resulting from the application of this logic are given in Table 9.

[29] ...\common\NorthOfDelta\American\NimbusHistMinQ.wresl

[30] ...\D1485\Run\Lookup\american_runoff_forecast.table

Table 9 - Historic flow requirements through Nimbus Dam, given storages (Oct. – Apr.) or storages plus forecasted inflows (Mar. – Sep.). Values marked "" were not tabulated, and are determined through linear interpolation.**

Folsom Storage (TAF)	Flow Requirement from Nimbus (cfs)											
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
0	0	0	0	0	0	0	0	0	0	0	0	0
80	**	**	**	**	**	188	188	188	188	188	188	281
100	500	500	500	500	500	250	250	250	250	250	250	375
200	600	500	500	500	500	**	**	**	**	**	500	375
300	**	500	500	500	500	500	500	500	500	500	500	**
400	750	500	500	500	500	500	500	500	500	500	500	**
500	**	**	**	**	**	500	500	500	500	500	500	**
550	**	**	**	**	**	**	**	500	500	500	500	**
575	**	1375	**	**	**	**	**	**	**	500	500	**
600	1250	**	**	**	**	**	**	**	**	500	500	**
635	**	**	1000	1000	**	**	**	**	**	**	**	**
650	**	**	**	**	**	**	**	**	**	**	**	500
685	**	**	**	**	1000	**	**	**	**	**	**	**
700	**	3000	**	**	**	**	**	**	**	**	**	**
760	**	3000	3000	3000	**	**	**	**	**	**	**	**
770	**	**	**	**	**	**	**	**	**	**	**	1000
772	**	3000	3000	3000	3000	**	**	**	**	**	**	**
800	2650	3000	3000	3000	3000	**	**	**	**	**	**	**
840	**	3000	3000	3000	3000	**	**	**	**		2000	**
960	**	3000	3000	3000	3000	**	**	**	**	2000	**	**
975	3000	3000	3000	3000	3000	**	**	**	**	**	**	**
1000	3000	3000	3000	3000	3000	750	750	**	**	**	2500	2500
1080	3000	3000	3000	3000	3000	**	**	**	2000	**	**	2500
1150	3000	3000	3000	3000	3000	**	**	**	**	2500	**	2500
1200	3000	3000	3000	3000	3000	**	**	2000	**	**	**	2500
1300	3000	3000	3000	3000	3000	**	**	**	2500	**	3000	2500
1450	3000	3000	3000	3000	3000	**	**	2500	**	**	3000	2500
1500	3000	3000	3000	3000	3000	**	1750	**	**	**	3000	2500
1600	3000	3000	3000	3000	3000	**	**	**	**	3000	3000	2500
1750	3000	3000	3000	3000	3000	1500	**	**	**	3000	3000	2500
1900	3000	3000	3000	3000	3000	**	**	**	3000	3000	3000	2500
2250	3000	3000	3000	3000	3000	**	3000	**	3000	3000	3000	2500
2300	3000	3000	3000	3000	3000	**	3000	3000	3000	3000	3000	2500
2500	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	2500
>2500	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	2500

Alternatively, when Folsom storages are below 200 TAF, CalSim-II defaults to the pre-CVPIA "18 MAR 1953 D-893 American River at H Street" baseflow requirement. This requirement varies by month, and is defined based on the value of the American River D893 Index. The resulting H-Street requirement is given in Table 10.

Table 10 - H-Street flow requirements for American River under the D1485 Step

Month	"H" Street Flow Requirement (cfs)	
	D-893 Water Year Type 1	*D-893 Water Year Type 2*
Oct	500	375
Nov	500	375
Dec	500	500
Jan	250	250
Feb	250	250
Mar	250	250
Apr	250	188
May	250	188
Jun	250	188
Jul	250	188
Aug	250	188
Sep	375	281

In addition to these historic flow schedules, Stability and AFRP flow requirements are set during the (b)(2) step of CalSim-II's runs. The Stability Flow requirement exists to maintain stable levee systems in the case of low-flow months. If outflows from Folsom fall below a threshold, defined in Table 11[31], then the current month's outflow must maintain a certain fraction of the previous month's outflow to sustain the structural integrity of the earthen riverbanks. Invocation of the stability requirements result in charges against the (b)(2) account.

Table 11 - Stability Flow requirements for Folsom Dam, coded to represent FWS management of b2 under the May 2003 Department of Interior (b)(2) Decision

	Previous month's release from Folsom-Nimbus (cfs)	Required Fraction to maintain in current month
November	<3,000	80%
December	<3,000	90%
January	<3,000	75%
February	<3,000	75%
March	<3,000	75%

The AFRP flow requirements, shown above in Table 12[32], are chosen based on storages in Folsom reservoir (October – April) or Folsom storage plus an inflow forecast (March – September). Forecasts for the American River change between February and May based on 99%, 90%, 75%, 50% exceedence probabilities for February, March, April and May through September, respectively.[33]

[31] ...\(b)(2)\Run\Lookup\AmerStability.table
[32] ...\(b)(2)\Run\Lookup\AFRP_AMER.table
[33] ...\(b)(2)\Run\Lookup\american_runoff_forecast.table

Table 12 – AFRP Flow Requirements for the American River as a function of Folsom storage or, between March and September, storage plus inflow forecasts through September. Values marked "" were not tabulated, and are determined through linear interpolation.**

Folsom Storages (TAF)	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
0	0	0	0	0	0	0	0	0	0	0	0	0
105	**	**	**	250	250	250	250	250	250	250	250	375
125	500	500	500	**	**	**	**	**	**	**	**	**
200	**	**	**	750	750	**	**	**	**	**	**	**
250	1000	1000	1000	**	**	**	**	**	**	**	**	**
300	1500	1500	1500	**	**	**	**	**	**	**	**	500
350	1750	1750		1500	1500	**	**	**	**	**	**	1000
400	**	**	1750	**	**	**	**	**	**	**	**	1250
450	**	**	**	1750	1750	**	**	**	**	**	**	**
500	**	**	**	**	**	**	**	**	**	**	500	**
575	**	2000	2000	2000	2000	**	**	**	**	**	**	**
600	**	2000	2000	2000	2000	**	**	500	500	500	1000	1750
650	1750	2000	2000	2000	2000	**	**	**	**	**	**	1750
700	2000	2000	2000	2000	2000	500	500	**	**	**	**	1750
725	2000	2000	2000	2000	2000	**	**	**	**	750	**	1750
750	2000	2000	2000	2000	2000	**	**	750	750	**	**	1750
775	2000	2000	2000	2000	2000	**	**	**	1000	1250	**	1750
800	2000	2000	2000	2000	2000	**	**	1250	1250	1500	**	1750
900	2000	2000	2000	2000	2000	750	750	1750	1500	**	1750	1750
950	2000	2000	2000	2000	2000	**	**	**	1750	**	1750	1750
967	2000	2000	2000	2000	2000	**	1000	**	1750	**	1750	1750
1000	2000	2000	2000	2000	2000	**	1250	**	1750	1750	1750	1750
1075	2000	2000	2000	2000	2000	**	1500	**	1750	1750	1750	1750
1150	2000	2000	2000	2000	2000	**	1750	**	1750	1750	1750	1750
1250	2000	2000	2000	2000	2000	1000	**	2000	1750	1750	1750	1750
1400	2000	2000	2000	2000	2000	**	**	**	2750	1750	1750	1750
1450	2000	2000	2000	2000	2000	**	**	3000	**	1750	1750	1750
1500	2000	2000	2000	2000	2000	**	**	3000	3000	1750	1750	1750
1750	2000	2000	2000	2000	2000	1500	**	3000	3000	1750	1750	1750
1800	2000	2000	2000	2000	2000	**	1750	3000	3000	1750	1750	1750
2050	2000	2000	2000	2000	2000	**	2750	3000	3000	1750	1750	1750
2100	2000	2000	2000	2000	2000	**	3000	3000	3000	1750	1750	1750
2500	2000	2000	2000	2000	2000	3000	3000	3000	3000	1750	1750	1750
>2500	2000	2000	2000	2000	2000	3000	3000	3000	3000	1750	1750	1750

Between the Historic, Stability, and AFRP requirements, the maximum requirement is not always applied. This results from the desire to conserve (b)(2) water for spring releases. In conditions when large (b)(2) allocations have been (or might be) made by the end of January, the AFRP requirement will be relaxed, and the next highest flow

requirement (between Historic and Stability) will be applied.[34] Table 13 explains this decision process.

Table 13 - Minimum Flow selection matrix, given that the stability requirement is invoked

Month	(b)(2) Account Condition	Folsom Minimum Flow Requirement
Dec	(b)(2) costs through Nov. >50 TAF	Max between (H St., Stability), but not above the AFRP requirement
Dec	(b)(2) costs through Nov. <50 TAF	Max (H St., Stability, AFRP)
Jan	(b)(2) costs through Dec. >150 TAF	Max between (H St., Stability), but not above the AFRP requirement
Jan	(b)(2) costs through Dec. <150 TAF	Max (H St., Stability, AFRP)
Jan	(b)(2) costs through Dec. + Expected AFRP Cost in Jan >200 TAF	Max between (H St., Stability), but not above the AFRP requirement
Jan	(b)(2) costs through Dec. + Expected AFRP Cost in Jan <200 TAF	Max (H St., Stability, AFRP)

The bottom two rows in Table 13 refer to "Expected AFRP Costs in January." This value is calculated as the sum of previous costs plus full AFRP flow requirements in January from Whiskeytown, Shasta/Keswick and Folsom/Nimbus. As indicated in the table, requirements that result in (b)(2) costs in excess of 200 TAF by the end of January will be relaxed. This relaxation is performed to conserve (b)(2) water through the spring.

[34] ...\(b)(2)\Run\(b)(2)Actions\(b)(2)Action1.wresl

New Melones/Goodwin Downstream Releases

CalSim-II models regulatory requirements for the Stanislaus River along three arcs, marked in Figure 10 as C10 (outflow from New Melones Reservoir), C16 (releases from Goodwin Dam), and C527 (a regulatory point upstream of Ripon). All releases from New Melones made for water quality and environmental purposes are routed through Goodwin Dam, and are unavailable for irrigation withdrawals.

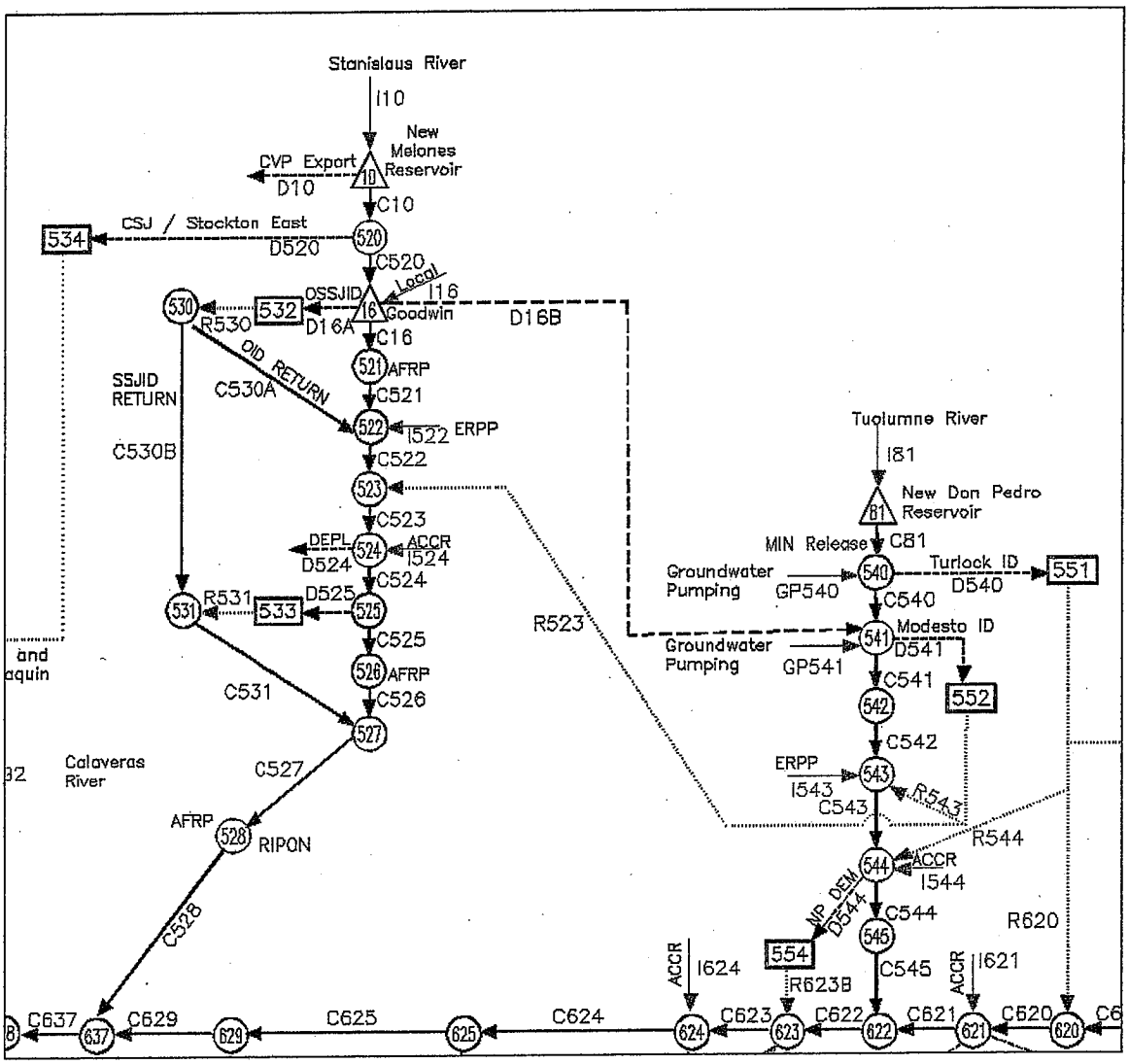

Figure 10 - CalSim-II schematic for the Stanislaus and Tuolumne Rivers

There are four general requirements governing minimum flows in the Stanislaus River below Goodwin Dam: dissolved oxygen standards, salinity standards, minimum flows and pulse flows for fish and wildlife in the Stanislaus River, and the Vernalis Adaptive Management Plan (VAMP) pulses.

Dissolved oxygen requirements for the Stanislaus River are defined below both New Melones and Goodwin[35]. As CalSim-II in its present form is incapable of simulating changes in dissolved oxygen concentrations, a surrogate flow prescription is given to represent the D.O. requirements. The flow prescription, shown in Table 14, is applied as part of all CalSim-II cycles.

Table 14 – Flow based dissolved oxygen criteria for the Stanislaus River[36]

Month	Requirement (TAF)
June	13.2
July	16.2
August	16.4
December	14.3

The Vernalis salinity requirements for the Stanislaus River are set below Goodwin.[37] If releases from Goodwin are sufficient to meet the standard, storage at New Melones will not be utilized for this purpose; otherwise the requirement will be meet through releases from New Melones. The requirement is based on limiting electrical conductivity (EC) values to not more than 700 and 1000 micromhos/cm for irrigation (April – August) and non-irrigation (September – March) seasons, respectively. CalSim-II approximates the required Stanislaus release by assuming a known salt concentration from several sources of flow in the Lower San Joaquin River system, specifically accretions and returns in the Stanislaus River, main-stem flows of the San Joaquin River before confluence with the Stanislaus River, and the west-side San Joaquin River return flows below the Stanislaus/San Joaquin confluence but upstream of Vernalis. Releases from Goodwin are made such that the aggregate concentration at Vernalis meets water quality standards.

All available water in the Stanislaus may be allocated to satisfy consumptive demands when in fact some portion should have been reserved to meet ecosystem objectives.

Pulse flow requirements for the Stanislaus River are defined as outflow from Goodwin and a point upstream from Ripon (node 525 in Figure 10)[38]. The flow requirement is determined through a three-step calculation. First the six-month New Melones forecast (NMF) is defined as the storage in February plus the sum of inflows through September based on a perfect forecast. Second, following the D1485 CalSim-II cycle, the NMF is used to determine an annual fishery allocation.[39] This allocation is given in Table 15. Finally, the fishery allocation is apportioned between pulse flow and minimum flow schedules, shown in Table 16 and Table 17.

[35] ...\Run\SanJoaquin\Stanislaus\DO.wresl
[36] ...\Run\Lookup\DO.table
[37] ...\common\SanJoaquin\WaterQuality\vernalis_wqmin.wresl
[38] ...\SanJoaquin\Stanislaus\stan_FW_pulse.wresl
[39] ...\Run\Lookup\stan_yr.table

Table 15 – Allocation to fisheries, based on New Melones Forecasts[39]

New Melones Forecast: NMF (TAF)	Fishery Allocation (TAF)
0	98
1,400	98
2,000	125
2,500	345
>3,000	467

Table 16 – Pulse flow requirement for the Stanislaus River, April 15 – May 15 [40]

Fishery Allocation (TAF)	Pulse Requirement (cfs)
0	0
98.9	500
>245.7	1,500

Table 17 – Minimum flow schedule for the Stanislaus River, in relation to Fishery Allocations [41]

	New Melones Forecast (x1,000 acre-feet)							
	0	98.9	155	200.6	256.2	311.5	410.2	466.4
January	-	125	150	250	275	300	350	400
February	-	125	150	250	275	300	350	400
March	-	125	150	250	275	300	350	400
April	-	250	300	300	300	900	1,500	1,500
May	-	250	300	300	1,500	900	1,500	1,500
June	-	-	125	200	200	250	800	825
July	-	-	125	200	200	250	300	625
August	-	-	125	200	200	250	300	525
September	-	-	125	200	200	250	300	400
October	-	110	110	200	250	250	350	350
November	-	200	225	250	275	300	350	400
December	-	200	225	250	275	300	350	400

The 1995 WQCP Vernalis minimum flow requirement is defined as soft constraints on releases from New Melones.[42] Releases from New Melones for Vernalis minimum flows are released through Goodwin, and cannot be diverted for other purposes. The standard is determined by (a) the San Joaquin water year type, (b) the day weighted average X2 requirement at Roe Island, Chipps Island and the Sacramento – San Joaquin River confluence (Table 18), (c) a restriction on flows at Goodwin and Ripon (1500 cfs) and (d) a cap set on the sum of New Melones releases between February and June. The New Melones outflow restriction is based on the New Melones forecast as shown in Table 19. Releases from New Melones are designed to make up any deficit in the Vernalis minimum flow requirement, up to release restrictions at New Melones, Goodwin, and Ripon.

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[40] ...\Run\Lookup\stan_pulse.table
[41] ...\Run\Lookup\stan_monfish.table
[42] ...\SanJoaquin\Vernalis\vernalis_min.wresl

Table 18 – Vernalis Requirement, by Water Year and X2 Position

San Joaquin Water Year Type	IF X2 is East of Chipps Island, Vernalis Requirement (cfs)	IF X2 is West of Chipps Island, Vernalis Requirement (cfs)
1	2130	3420
2	2130	3420
3	1420	2280
4	1420	2280
5	710	1140

Table 19 – Annual Release Restriction at New Melones[43]

New Melones Forecast (TAF)	Release Restriction at New Melones (TAF)
0	0
1,400	0
2,000	0
NMF ≥ 2,500	1,000

VAMP are target flows in the San Joaquin River at Vernalis during April and May, the obligation for which is shared by water users on all of the eastside San Joaquin River tributaries and the beneficiaries of the exchange pool at Mendota. In the event that other CalSim-II operations leave a deficit in the VAMP account, a portion of the deficit must be offset by release to the lower Stanislaus below Goodwin Dam. Table 20 identifies the VAMP obligation of the Stanislaus River water users and other VAMP regulated rivers, as a function of the VAMP deficit.

Table 20 – New Melones release requirements (TAF), relative to VAMP deficits

VAMP Deficit (TAF)	Merced ID: Merced River	OID: Stanislaus River	Exchange: Mendota Pool	MID/TID: Tuolumne River
0	0	0	0	0
25	25	0	0	0
35	25	10	0	0
40	25	10	5	0
50	25	10	5	10
61.5	36.5	10	5	10
66.1	36.5	14.6	5	10
68.4	36.5	14.6	7.3	10
73	36.5	14.6	7.3	14.6
81.5	45	14.6	7.3	14.6
84.9	45	18	7.3	14.6
86.6	45	18	9	14.6
90	45	18	9	18
100	55	18	9	18
104	55	22	9	18
106	55	22	11	18
Deficit ≥ 110	55	22	11	22

[43] ...\Run\Lookup\stan_yr.table

CalSim-II sequences the access to storage in New Melones Reservoir to meet these various water quality and environmental flow requirements. The general sequence of access is as follows:

1) In the first CalSim-II model cycle, irrigators access storage and inflows to New Melones and Goodwin, up to their current monthly demand.
2) Throughout the remaining model cycles, inflows to and storage in New Melones and Goodwin are made available for water quality and environmental flow requirements in the Lower Stanislaus River and in the Delta.

This sequencing suggests that water delivery objectives are paramount relative to environmental flow requirements. The implication is that all available water may be allocated to satisfy consumptive demands when in fact some portion of available storage should have been reserved to meet ecosystem objectives.

Delta Outflow Requirements

CalSim-II represents the basic outflow requirements from the Sacramento-San Joaquin Delta through a demand arc marked as D407 in

Figure 11. Generally, the D407 flow requirement is a composite of the X2 requirement and other Delta outflow standards. This standard is set by evaluating (1) the Minimum Required Delta Outflow (MRDO) in concert with either (2a) the ANN Delta Outflow Requirement or (2b) the G-Model. In the CalSim-II model evaluated for this review, the final Delta outflow requirement is the maximum between MRDO and the ANN.

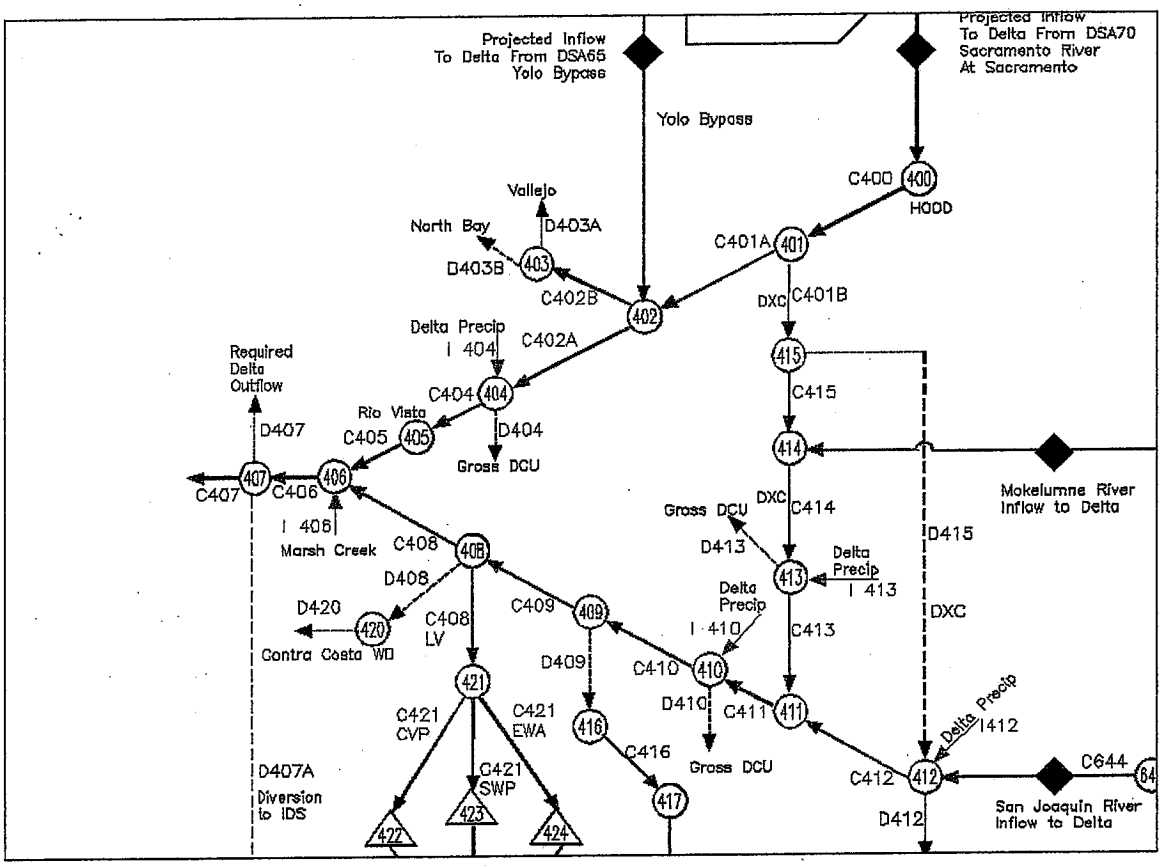

Figure 11 - CalSim-II Representation of the Sacramento-San Joaquin Delta

The Minimum Required Delta Outflow is calculated by evaluating eight separate flow requirements:

i.	Striped Bass Survival/Spawning	(D1485 Flow Requirement, for (b)(2) accounting)
ii.	Suisun Marsh Flow Requirement	(D1485 Flow Requirement, for (b)(2) accounting)
iii.	60-day Suisun Marsh Flow Requirement	(D1485 Flow Requirement, for (b)(2) accounting)
iv.	Flood Envelope Flow Requirement	(D1485 Flow Requirement, for (b)(2) accounting)
v.	X2 at Roe Island/Port Chicago	(D1641, (b)(2), and SDIP Flow Requirement)
vi.	X2 at Chipps Island	(D1641, (b)(2), and SDIP Flow Requirement)
vii.	X2 at the Sacramento-San Joaquin confluence	(D1641, (b)(2), and SDIP Flow Requirement)
viii.	Absolute Minimum Delta Outflow	(D1641, (b)(2), and SDIP Flow Requirement)

These requirements specify (a) the quantity of Delta outflow required to satisfy the requirement, (b) the day the requirement begins, and (c) the day the requirement ends. A composite of these standards is sent by CalSim-II to an external FORTRAN routine that determines the minimum required Delta outflow quantity by arraying the flow requirements across the days in a month, finding the maximum value for each day and averaging these daily maximums to get a monthly value. This procedure is required because CalSim-II runs on a monthly time step. While this is common for water resource planning models, it complicates the simulation of environmental regulation in the Delta which has been designed to manage day to day conditions in the system.

These standards are more related to protecting consumptive uses than creating optimal environmental conditions.

The first four flow requirements are considered by MRDO during the D1485 model cycle (requirements i-iv), but not during subsequent cycles. Increases in reservoir releases or decreases in South of Delta exports that result from changes to these policies during later model cycles are charged to the (b) (2) account.

EWC

Table 21 – Striped Bass survival and spawning Delta outflow schedules

	Delta outflow schedule (cfs) by water year designation						
	W[44] (1)	AN[44] (2)	D[44] (3)	C[44] (4)	Dry-Dry[44]	Wet-Dry[44]	Low Snow[45]
October	4000	4000	4000	4000	3000	2500	2500
November	4500	4500	4500	4500	3500	2500	2500
December	4500	4500	4500	4500	3500	2500	2500
January	2500	2500	2500	2500	2500	2500	2500
February	2500	2500	2500	2500	2500	2500	2500
March	2500	2500	2500	2500	2500	2500	2500
April	6700	6700	6700	6700	6700	6700	6700
May	14000	14000	11400	4300	3300	4300	6500
June	14000	10700	9500	3600	3100	3600	5400
July	10000	7700	6500	3200	2900	3200	3600
August	2500	2500	2500	2500	2500	2500	2500
September	2500	2500	2500	2500	2500	2500	2500

The Striped Bass survival and spawning requirement defines Delta outflows from May 6th – April 14th (excluding April 15th – May 5th). The level of flow required is set by three indices: the D1485 Fish and Wildlife Standards Index[46], the D1485 Subnormal Snowmelt Index[47], and the D1485 Project Deficiency Index[48]. Under normal circumstances, the flow requirement corresponds to the D1485 water year index, shown in the first four columns of Table 21. For sequential dry water years, the requirement

[44] ...\D1485\Run\Lookup\NdoBass.table
[45] ...\D1485\Run\Lookup\NdoBassSnow.table
[46] ...\D1485\Run\Wytypes\wytypes.wresl [NOTE: defined in wresl code as the product of 2 other wytypes]
[47] ...\D1485\Run\Lookup\wytypeSnow.table
[48] ...\D1485\Run\Lookup\wytypeDefic.table

goes to the Dry-Dry schedule. In a dry year following a wet year, the Wet-Dry schedule is invoked. If the water year type is either dry or critical *and* there is a low snowpack forecast (as determined by the D1485 Subnormal Snowmelt Index) the Low Snow schedule in the final column governs the standard.

When the D1485 Project Deficiency Index is triggered (an index value of 1), then the April 1st and 14th schedule can be reduced to 2,500 cfs. Likewise, in a critical D1485 water year the same reduction is allowed.

The Suisun Marsh flow requirement is set based on two water year indices: the D1485 Fish and Wildlife Standards Index[49], the D1485 Subnormal Snowmelt Index[50]. This requirement specifies a default 2,500 cfs Delta outflow flow throughout the year. Criteria for deviating from the default flow requirement are specified in Table 20.

Table 20: Conditional Wet Water Year Suisun Marsh spring flows

D1485 F&W Index	D1485 Subnormal Snowmelt Index	Flow Requirement	Period of Flow Requirement
Wet	Low Snow	10,000 cfs	February - April
Wet	Not Low Snow	10,000 cfs	February - May

The 60-day Suisun Marsh Flow Requirement operates between January and April. This requirement is 2,500 cfs by default. In non-wet (i.e. index $\neq 1$) and non-dry (i.e. index $\neq 4$) water years, the flows are required to be 12,000 cfs for two months between January and April. The months do not have to be sequential, and CalSim-II accounts for the months during this period when the requirement is met.

The three-reservoir Flood Envelope requirement is set by North of Delta storage conditions. In the case that two of the North of Delta projects (Shasta, Folsom, and/or Oroville) have storage in zone 5 (high/spill storage reservoir zone), Delta outflow is required to be 6,600 cfs. Otherwise, the flow requirement defaults to 2,500 cfs.

The Post-D1641 X2 Outflow Requirements (requirements v-viii) are calculated by tracking the 2ppt (X2) bottom isohaline line between the months of February and June. CalSim-II calculates a net monthly flow requirement for three locations (Roe Island/Port Chicago at river mile 39, the Sacramento-San Joaquin Confluence at river mile 50, and Chipps Island at river mile 74).

The first step in setting the X2 requirements is determining where the X2 isohaline line is situated at the beginning of a month or period (BOP). This is determined using the Kimmerer-Monismith equation[51], which references the previous month's North of Delta outflow (NDO) which enters the Delta and the X2 location at the beginning of the previous month (Equation 1).[52]

---

[49] ...\D1485\Run\Wytypes\wytypes.wresl [NOTE: defined in wresl code as the product of 2 other wytypes]

[50] ...\D1485\Run\Lookup\wytypeSnow.table

[51] It is important to note that this regression equations were develop using data from historic Delta export conditions and that future changes that include dramatic changes in Delta exports may compromise the use of these relationships.

[52] ...\Run\Delta\MRDO\X2\X2req.wresl

Equation 1	$X2_{BOP} = \mathbf{122.2} + \mathbf{0.3278} * X2\text{-}Location_{\text{beginning of previous month in kilometers}} - \mathbf{17.65} * log_{10}(NDO_{\text{previous month in cubic feet per second}})$

If the calculated BOP X2 location is greater than 66.3 km (river mile 41) then the calculation of the Roe Island requirement is invoked. If the BOP X2 position is at, or below the 66.3 km point, then the Roe Island requirement is bypassed. If the Roe Island X2 requirement is triggered, the number of days that the Roe Island X2 constraint is expected to be a controlling Delta outflow requirement is referenced from a lookup table.[53] This number varies by month and by water year. The Delta outflow required to satisfy Roe Island is capped at 29,200 cfs, and is calculated Equation 2.[54]

Equation 2	$Q_{\text{Roe Island Requirement}} = 10 \wedge [(\mathbf{122.2} + \mathbf{0.3278} * X2\text{-}Location_{\text{beginning of previous month}} - \mathbf{64}) / \mathbf{17.65}]$

If Roe Island is triggered, a further calculation (Equation 3)[55] determines where X2 will be situated at the end of the month as a result of meeting the Roe Island outflow requirement.

Equation 3	$X2\text{-}Location_{\text{Post Roe Island}} = \mathbf{122.2} + \mathbf{0.3278} * X2\text{-}Location_{\text{beginning of month}} - \mathbf{17.65} * Log_{10}(Q_{\text{Roe Island Requirement}})$

In the case that Roe Island standard is invoked, the number of days in which the Chipps Island requirement controls the Delta outflow requirement (same lookup table as the Roe Island standard) [56] is reduced by the number of Roe Island days. The Chipps Island flow requirement is capped at 11,400 cfs, and is calculated using Equation 4[57].

Equation 4	$Q_{\text{Chipps Island Requirement}} = 10 \wedge [(\mathbf{122.2} + \mathbf{0.3278} * X2\text{-}Location_{\text{Post Roe Island}} - \mathbf{74}) / \mathbf{17.65}]$

Equation 5 [58] then determines where X2 will be situated as a result of meeting the Chipps Island outflow requirement.

---

[53] ...\D1641\Run\Lookup\x2days.table
[54] ...\Run\Delta\MRDO\X2\X2req.wresl
[55] ...\Run\Delta\MRDO\X2\X2req.wresl
[56] ...\D1641\Run\Lookup\x2days.table
[57] ...\Run\Delta\MRDO\X2\X2req.wresl
[58] ...\Run\Delta\MRDO\X2\X2req.wresl

Equation 5	$X2\text{-}Location_{Post\ Chipps\ Island} = \mathbf{122.2} + \mathbf{0.3278} * X2\text{-}Location_{beginning\ of\ month} - \mathbf{17.65} * Log_{10}(Q_{Chipps\ Island\ Requirement})$

The Sacramento-San Joaquin Confluence flow requirement is reduced by the number of days in which either the Roe or Chipps Island requirements are being met (the greater between the two). In the case that Roe Island is not triggered, then the number of days in which the Confluence requirement would be a controlling outflow requirement (same lookup table as the Roe and Chipps Island standards) [59] is reduced by the number of Chipps Island days. The Confluence flow requirement is capped at 7,100 cfs, and is calculated using Equation 6[60].

Equation 6	$Q_{Chipps\ Island\ Requirement} = 10 \wedge [(\mathbf{122.2} + \mathbf{0.3278} * X2\text{-}Location_{Post\ Roe\ Island} - \mathbf{74}) / \mathbf{17.65}]$

To generate the final X2 requirement, the Roe Island requirement is assumed to begin on day 1 and end after the pre-determined period of time. Any remaining Chipps Island requirements begin on the day after the Roe Island requirement is met. Lastly, any Sacramento-San Joaquin Confluence flow requirements begin on the day after the Chipps Island requirements are met. The Confluence requirement then continues through to the end of the month.

Observation of the results of CalSim-II evaluated during this review reveal that during May and June of the 1924, 1931, 1939, 1976, 1977, 1990, 1991 and 1994 water years, zero X2 days were required, apparently because the projected 40-30-30 Sacramento River Index fell below 8.1 MAF in the month of May. During these situations, a 4,000 cfs minimum flow standard is maintained.

ask Dave

The ANN Delta Outflow Requirement is computed in an external FORTRAN routine (an Artificial Neural Network). Current physically based models, such as the DSM-II, report salinity levels as a function of Delta inflows and exports, and not visa-versa. CalSim-II's ANN was designed to reverse this functional relationship in a procedure that would otherwise be a lengthy iterative process. The ANN bases its decisions on the current month's flow (the only variable), on antecedent flow conditions, and on the current level of salinity at each station. Standards that emerge from the ANN are designed to protect water quality at various points throughout the Delta. These standards are more related to protecting consumptive uses than creating optimal environmental conditions

CalSim-II takes a composite of all of the preceding flow standards in order to arrive at the minimum Delta outflow assigned to arc D407 shown in the schematic found in Figure 11.

[59] ...\D1641\Run\Lookup\x2days.table
[60] ...\Run\Delta\MRDO\X2\X2req.wresl

Full Environmental Compliance CalSim-II Formulation Work Plan

Based on the insights gleaned from this environmental review, it is possible to begin sketching out a work plan for developing a legal compliance formulation of the CalSim-II model. Before launching in to this exercise, however, it is worth forwarding a few general impressions that can place the recommended work plan items in a proper context.

1. Any water resources model, including CalSim-II, can be improved through continued refinement of its underlying assumptions. The following work plan is offered in the spirit of constructively contributing to continued improvements to the CalSim-II model.
2. Based on the sub-set of CalSim-II logic reviewed for this report we are confident in the validity of our conclusions that we used them to motivate the following proposed work plan.
3. Like most water resource planning models, CalSim-II is path dependent. Much of the model logic governing the simulated system operation is governed by the state of the system at a particular moment in time, and this state will evolve differently under alternative assumptions about the environmental regulations governing system operations. This means that examining model code is not a sufficient method for understanding the implications of different model formulations. In the end, changes in the code must be implemented and the implications of these changes must be measured by examining model output. For these reasons recommend that the CalSim-II development team implement this workplan and evaluate the magnitude of potential changes in model output.

With these impressions on the table, our conclusion after having completed the environmental review are that the work plan for creating a full environmental compliance formulation should focus on:

- Removing all vestiges of perfect foresight from the definition of environmental regulations governing system operations;
- Revising the (b)(2) accounting logic to align it with what we consider to be the current interpretation of the CVPIA; and
- Introducing a minimum flow standard from the San Joaquin River.

Removing Perfect Foresight from the Definition of Environmental Regulations

In developing the work plan for this CalSim-II model improvement, we adopt the assumption implicit in the definition of environmental regulations as constraints on system operations, namely that they are of a higher priority than any other water management objectives in the system. As such, at any particular moment in a CalSim-II simulation, the model should anticipate that environmental regulations should be met to the fullest possible extent, unless and until conditions dictate that environmental regulations can be relaxed. This is not the approach taken in the current CalSim-II formulation, which relies on water year indices defined during the February or March time step, to determine if environmental regulations can be relaxed.

this allows too much pumping and export south

For example, consider the definition of the obligation associated with the (b)(2) account as described in Table 1. In February, with the benefit of perfect foresight, a determination is made regarding whether the annual (b)(2) obligation is 800 TAF, 700 TAF, or 600 TAF. In order to meet the full environmental compliance standard and honor the top priority assumption implicit in the definition of environmental constraints, the strictest possible regulations must be anticipated until enough information is available to decide otherwise. In much the same way that CalSim-II uses forecasts to introduce uncertainty into its promised water deliveries, uncertainty needs to influence the establishment of environmental regulations.

As discussed above, in calculating the value of WSI during the February time step, CalSim-II uses the level of precipitation that has been exceeded 99% of the time during the remaining months of the water year in order to forecast what reservoir inflow will be available for allocation during the coming months. This threshold drops to 90% during the March time step, 75% during the April time step, and 50% during the May time step. This is a prudent risk management strategy, as it assumes the worst when much is still unknown about what the future holds. A corollary to this prudent posture is to also assume that environmental constraints will be at their most stringent when much is still unknown about what the future holds. Perfect foresight is not consistent with this risk management posture.

To satisfy a full environmental compliance standard, all of the indices used in CalSim-II need to be calculated dynamically based on prudent forecasts about what the future may hold. In February the question should be what are the environmental constraints that will be in place going forward assuming that future inflows associated with the level of precipitation exceeded 1% of the time during the remainder of the water year is used to forecast the relevant indices. The answer to this question will surely be the most stringent set of environmental constraints. As time passes and the future becomes more certain then the level risk tolerance related to calculating water year indices can be increased. During the March time step the question would be what are the environmental constraints that will be in place going forward assuming that future inflows are associated with the level of precipitation exceeded 10 % of the time during the remainder of the water year are used to update the relevant indices. In April the threshold would drop to 25% and then to 50% in May. By applying this corollary to the risk tolerance already applied to project water supply availability, the top priority environmental constraints would not be weakened until there was justification for doing so.

Under this formulation, the calculation of the water supply index and use of the WSI-DI and DelCar Curves to translate WSI into a promised level of deliveries to meet current water demands does not change. During years when perfect foresight allowed for an early weakening of environmental constraints under the old formulation, however, under the new formulation the promised deliveries will be subject to more stringent environmental constraints during some portion of the February to June period. This may mean that CalSim-II could fail to meet the water delivery promises generated by the current set of risk management curves (the red dot in Figure 3). In keeping with the risk tolerance philosophy implicit in these curves, they should be retrained as part of the full

environmental compliance formulation in the event that significant delivery shortfalls materialize so that less water is promised to other water uses in the system.

Activity 1: Internalize the calculation of water year indices used to set environmental regulations.

This activity involves moving the values of water year indices used to set environmental regulations from external look-up tables where they are stated with perfect foresight into the actual WRESL code where they will be updated continuously based on forecasted inflows.

Activity 2: Define risk tolerance posture with respect to anticipated environmental regulations.

We propose that the 1% exceedence probability of forecasted inflows be used for the months of October-February. This will assure that the strictest possible environmental regulations will be anticipated during that period when large amounts of uncertainly exist about the future. As a corollary to the risk tolerance implicit in the forecasts used to support water allocation, assume that the 10% exceedence inflow will be used in March, 25% in April, and 50% in May. By June that water year index can be set definitively for the remainder ~~of the water year.~~

Activity 3: Construct the forecasted inflow data tables that will drive the continuous calculation of water year indices.

The forecasted inflows used to support water allocation are read in to CalSim-II from an external file. A similar set of anticipated inflow tables would need to be developed to capture the risk tolerance posture adopted for anticipating environmental regulations.

Activity 4: Implement WRESL code required to adjust environmental regulations based on the continuous evolution of water year indices.

In the current version of CalSim-II, the environmental regulations create a pre-determined constraint on simulated system operations. The new formulation would require WRESL code to look-up the regulations associated with an evolving series of water year indices.

Activity 5: Update the WSI-DI and DelCar curves to reflect the change in underlying constraint set.

As the underlying constraint set used to develop the WSI-DI and DelCar curves, which was based on the application of perfect foresight in setting environmental constraints, will be modified by implementing the preceding activities, it may be necessary to update these risk tolerance defining curves as higher environmental flows will likely be required during the late winter and early spring months.

REVISING THE (B)(2) ACCOUNTING LOGIC

While the method used in applying environmental actions against the (b)(2) account has been the subject of legal and administrative wrangling since the passage of CVPIA in 1992, we believe that the logic employed in CalSim-II to capture the currently accepted accounting methodology is not entirely consistent with the current legal interpretation of

the Act. We recognize that this conclusion derives from our interpretation of current law, so it is probably worthwhile to articulate our position on this point.

First, we believe that the intent of (b)(2) was to rededicate a portion of the CVP yield back to fish and wildlife enhancement objectives, primarily the restoration of anadromous fish. While courts have found that Delta water quality actions, which benefit Delta resident fish and consumptive water users relying on water drawn from the Delta, could be considered as acceptable charges against the (b)(2) account, they stipulated *"as long as the allocation gives effect to the hierarchy of purposes established in section 3406(b)(2)"*. Here we believe the intent was clear as Section 3406(b)(2) of the Central Valley Project Improvement Act states that the CVP will:

> "dedicate and manage annually 800,000 acre-feet of Central Valley Project yield for the **primary purpose** of implementing the fish, wildlife, and habitat restoration purposes and measures authorized by this title; to assist the State of California in its efforts to protect the waters of the San Francisco Bay/Sacramento-San Joaquin Delta Estuary; and to help to meet such obligations as may be legally imposed upon the Central Valley Project under State or Federal law following the date of enactment of this title, including but not limited to additional obligations under the Federal Endangered Species Act."

We also believe that fish, wildlife, and habitat restoration purposes and measures specifically include the anadromous fish doubling goal included in the Act.

The current CalSim-II formulation turns this notion of primacy upside down by fully changing water quality actions to (b)(2), as well as other non-fish motivated actions, while using fish and wildlife actions to make up any remaining obligations to the (b)(2) account. This stems from the fact that the D-1641 step is run before the (b)(2) step and that all changes in the release and export metrics associated with the difference between the D-1485 and D-1641 steps are charged to (b)(2) with perfect foresight for the water year. In addition, in reviewing various environmental regulations we discovered several other actions of questionable fish and wildlife value that are charged to (b)(2). All this occurs before any fish and wildlife (b)(2) action occurs.

We propose an alternative course of action that envisions the implementation of a new step in the CalSim-II formulation. In keeping with its implicit focus on anadromous fish recovery, this new step is provisionally referred to as the salmon step. The sequence of (b)(2) actions currently used in CalSim-II, as shown in Table 21, is a good starting point for developing the elements of the salmon step. We feel that the highest priority should be assigned to AFRP releases (currently priority 3) as these are designed specifically to meet the anadromous fish-doubling target that was also part of the CVPIA. If this were the case, the type of limitations on AFRP releases that are contained in Table 8 and Table 13 would be unnecessary as these are intended to minimize AFRP flows when significant credits to the (b)(2) account can be derived from the D-1641 step.

A second level of priority would be assigned to the VAMP export priorities (current priority 2), as well as the pre- and post-VAMP restrictions (currently priorities 7 and 4 respectively). As all of these actions would occur after the October to March period

during which AFRP flows would be implemented, it should be possible to consider the three components of the VAMP export limitations as a single action.

The final actions in the new salmon step would include the export ramping and the 3000 cfs export limit actions anticipated for the month of June. As these occur after the VAMP export restrictions, a decision will be made in June as to whether they are necessary.

Action Description	Priority of Action	Reserve* for Action (taf)	Balance† Req'd to Trigger Action (taf)	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
WQCP Support (D-1641)	1														
AFRP Releases	3		1												
Export Reductions (150 taf)	6	150	1+2+3+4+5+6												
VAMP Export Restrictions	2	115													
Post VAMP Export Restrictions	4	45	1+4												
Export Ramping	5	60	1+5												
3000 cfs Export Limit	2														
Pre VAMP Export Restrictions	7	40	1+2+4+4+7												
Export Reductions (35 taf)	8	35													

* Average reserve amount. Actual reserves may depend on water year type and/or other hydrologic conditions. Reserves for multi-month actions represent the amount required to complete the entire actions.

† (b)(2) balance after accounting for past costs and current month WQCP(D-1641) support. Values refer to the sum of the reserve amounts associated with the action priorities.

A couple of clarifying points are useful at this point in the discussion. Based on the removal of perfect foresight from the establishment of environmental regulations described above, the exact (b)(2) obligation will not be known as the AFRP actions are implemented between October and March. If this creates a situation whereby AFRP actions result in greater charges against (b)(2) than are finally called for based on the evolution of water year indices, the excess will be changed against the (b)(2) account during the following water year.

Second, several local environmental regulations that are of questionable fishery value, namely the stability criteria on the Sacramento and American Rivers and the diversion of water that would otherwise spill in the Trinity system, are currently charged against (b)(2). In implementing the new salmon step, these charges would not be allowed.

Finally, as the proposed salmon actions are implemented sequentially, there is no need to define and manage reserves and triggers as is the case in the current (b)(2) step. The proposed anadromous fish related actions would simply be implemented in sequence until the (b)(2) obligations is satisfied.

Following the completion of the new salmon CalSim-II step, the current D-1641 step would be implemented. This step contains regulatory drivers related to Delta water quality to protect Delta resident fish and water users who draw water from the Delta. It

seems to us that these two drivers are so tightly bound in the D-1641 step that it is unreasonable to separate actions driven by fishery objectives from those driven by consumptive water needs. Therefore we acknowledge that should any remaining (b)(2) obligations remain after the new salmon step, all D-1641 actions can be used to satisfy this obligation, even if they are designed primarily to protect the interest of consumptive water users. As in the case of the new salmon step, D-1641 actions will be implemented sequentially, although in this step, D-1641 actions will continue even after (b)(2) obligations are retired.

If additional (b)(2) obligations remain at the end of the D-1641 step, then a revised (b)(2) step will be implemented. This step will sequentially implement the December-January export reductions, the February-March export reductions, and the May export limit actions described in Table 21, as needed until the (b)(2) obligation for the year is retired. If (b)(2) obligations remain following this step, they will be forgiven.

While there will be surely be discussion of the legal underpinning of this alternative formulation of the (b)(2) accounting logic, we do not feel that the assignment of first priority to Delta water quality objectives relative to (b)(2) obligations complies with the intend of CVPIA or court findings. The following steps are needed to implement this aspect of the compliance work plan.

Activity 1: Create and implement the new salmon CalSim-II step.
This step will involve adding a new step that sequentially implements the AFRP, VAMP export reductions, and June actions up to the limit of the (b)(2) account that will evolve over the course of the water year according to the forecast based water year indices. Stability releases and Trinity transfers to avoid spills will not be charges against (b)(2) in this step.

Activity 2: Implement conditional logic to govern the implementation of the final revised (b)(2) CalSim-II step.
Under the proposed CalSim-II formulation the (b)(2) obligation may or may not be retired following the D-1641 step. CalSim-II logic must be developed to control the flow of the model depending on the status of the (b)(2) account at the end of the D-1641 step. This conditional flow is depicted in Figure 12.

INCLUDING MINIMUM INSTREAM FLOWS FOR THE SAN JOAQUIN RIVER BELOW FRIANT

The final proposed environmental compliance element is the inclusion of a minimum instream flow requirement for the San Joaquin River below Friant Dam. This is motivated by the recent ruling that called upon the Bureau of Reclamation to release sufficient water to restore the anadromous fishery in the reach between Friant and the Merced River confluence. While the ruling provided no specific guidelines as to release schedule required to satisfy this obligation, it is clear that a release regime will be a part of the environmental regulatory structure in the future and needs to be implemented in CalSim-II. The following work plan steps are needed to accomplish this goal.

Activity 1: Define a release schedule
As part of the failed settlement negotiations, several proposed release regimes for the lower San Joaquin River were developed. This task would involve deciding on two flow regimes from the proposed alternatives that will bracket the potential flow regime.

Activity 2: Implement the Friant Release Logic
Add WRESL code to CalSim-II that can read the release requirements from a look-up table.

Activity 3: Perform Sensitivity Analysis on the two Release Regimes
Run the model with both release regimes and assess the sensitivity of model results to the difference. If the model is highly sensitive, two baselines may be needed. If the model is insensitive, institute a compromise between the two as part of the CalSim-II baseline.

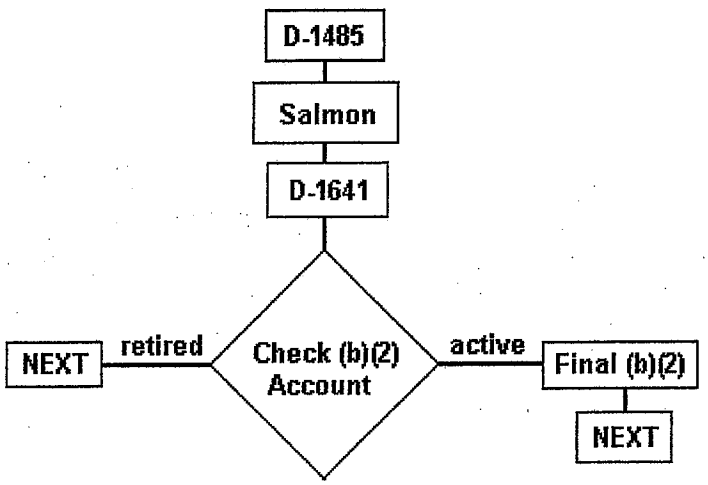

Figure 12: Proposed CalSim-II Flow Chart

Environmentally Preferred CalSim-II Formulation Work Plan

As could reasonably be expected, the definition of an environmentally preferred CalSim-II formulation is a more ambitious activity than the comparison of the current model formulation against a standard of regulatory compliance. It implies that the management of California water systems will be adjusted until the point that ecosystems protected under current law are restored rather than a legalistic determination of whether or not the model accurately represents current regulations that may not be meeting restoration objectives. While the preceding discussion focusing on the full environmental compliance workplan was quite focused and detailed, the following discussion of an environmentally preferred formulation will be broader. In addition, our suggestions regarding required modifications to the CalSim-II code associated with the environmentally preferred formulation will be more strategic and less prescriptive.

With this qualification on the table, our conclusions after having completed the environmental review are that the work plan for creating a full environmental compliance formulation should focus on:

- Adapting several existing regulations to conform more with future conditions that are either anticipated or desired and would avoid the legal impacts associated with a failure to achieve real aquatic ecosystem restoration.
- Introducing operational flexibility to the CalSim-II code so that alternative sets of environmental flow regimes, beyond the establishment of minimum instream flows, can be simulated and evaluated.

In each case, several existing regulations or alternative flow regimes are presented. For each, a possible approach for CalSim-II modifications associated with the specific regulation or regime are summarized without defining a specific set of activities required to implement these modifications. These activities can be developed once an agreement has been reached to implement a specific element of the environmentally preferred formulation.

Adapting the Representation of Existing Regulations

The following changes to specific regulations are proposed for the environmentally preferred CalSim-II formulation. As with the full compliance workplan, these items are not meant to be exhaustive as a comprehensive inventory of all existing regulations was not performed. They are representative, however, of the kind of incremental improvements in the environmental regulatory structure that may be of interest.

Changes to the Vernalis Salinity Standard

Action: CalSim-II should be reformulated to evaluate an EC standard on the San Joaquin River at a point upstream of the Stanislaus River confluence. The contribution of a San Joaquin River fishery release schedule from Friant Dam should be considered as a source of water to help meet this standard. Doing so will dramatically reduce the amount of water that needs to be released from New

Melones Dam to dilute the salt load at Vernalis, shifting responsibility for San Joaquin salinity control to all water users on the San Joaquin River.
Possible Approach: This can be accomplished by reconfiguring reservoir release arcs upstream of the Stanislaus to include sub-arcs for meeting the salinity standard. CalSim-II is incapable of directly evaluating salinity as a function of flow, so this suggestion requires that new empirical relationships between flow and salinity be developed with higher spatial and temporal resolution than the flow salinity relationship now used to control the Vernalis salinity standard.

Shift the position of X2

Action: The X2 compliance point should be moved to the western Delta when this would most benefit conditions for Delta-dependent species. Closing the Delta Cross Channel Gates as recommended in the AFRP to assist salmon smolt outmigration will affect the location of X2 and move it further to the west than would otherwise be the case. Limiting Delta export pumping when smolts are in the Delta will also result in X2 being further to the west. The combined effect of changes and Delta operations and the maintenance of X2 in the western Delta needs to be evaluated in CalSim-II.
Possible Approach: Evaluate the latest scientific understanding concerning the estuarine water quality needs of key species during their various life stages in order to refine where the X2 standard should be set. Update the Kimmerer-Monismith equation and the supporting data tables to accommodate this refined understanding, including some consideration of the operation of the cross channel gates and restrictions on Delta exports. Introduce these changes into CalSim-II.

Changes to Folsom/Nimbus Operations

Action: A portion of Folsom reservoir storage space should be held in reserve to assure adequate water supply for maintaining targeted instream flows and water temperatures for salmonid fishes at levels identified by AFRP and/or Sacramento Water Forum.
Possible Approach: This can be accomplished through either the development of a dummy reservoir, or the adjustment of the "dead storage" level to absorb target storage reservations. Dead storages have very high weights, which means that the model resists releasing from the dead storage pool until the most severe conditions are encountered.

Action: Increases in Sacramento Water Forum demand above current levels should have lower priority than instream flow, temperature and reservoir reserves for environmental use.
Possible Approach: Incremental increases to Sacramento River withdrawals beyond the 2000 Level of Development could be performed in cycles subsequent to those considering environmental flow objectives, and be given a weight corresponding to junior water rights holders or interruptible deliveries.

Action: Reduce reliance on the American River for maintaining Delta water quality standards and cap Folsom/Nimbus releases for the purpose of meeting

Delta outflow requirements at 4000 cfs. This would result in greater sharing of the responsibility for meeting Delta water quality standards between all Sacramento Valley tributaries. It may also be possible to share this responsibility with San Joaquin Valley tributaries in light of the fact that upper San Joaquin River releases will most likely occur in the future.

Possible Approach: This suggestion requires the inclusion of non-CVP reservoirs (particularly Oroville) in the call for both X2 and the Water Quality standards within the ANN. The cap on reservoir releases is, however, relatively straightforward to achieve in CalSim, as it would require logic similar to the manner in which orchards downstream of New Melones are protected from high flows. Spreading responsibility for Delta water quality standards to the San Joaquin River tributaries would require the introduction of feedback between North of Delta operations and the simulated San Joaquin River Delta inflow contribution.

Modify Delta Export Restrictions

Action: The benefits of enhanced Delta outflow, as well as more balanced Delta inflows associated with changes to Folsom/Nimbus operations, should be complemented by increased constraints on exports. During the February 1-June 15 period, exports should be capped at 35% of total inflow and/or <200% of Vernalis flow (2:1 export:Vernalis ratio).

Possible Approach: The current configuration of CalSim-II could be changed to accommodate this policy suggestion without major revision.

Action: VAMP (enhanced San Joaquin tributary flows + curtailed exports) should be expanded from 31 days to 61 days (April 1- May 31). The upper San Joaquin River releases should be included as a potential contribution to satisfying VAMP.

Possible Approach: The current configuration of CalSim-II could be changed to accommodate this policy suggestion without major revision.

Action: From October 1-Feb 29, a total of 60 days of DCC gate closures should be allowed.

Possible Approach: The current configuration of CalSim could be changed to accommodate this policy suggestion without major revision.

Refinement of the (b)(2) Accounting Rules

Action: Offset and Reset accounting rules should be used. If (b)(2) water is released from a reservoir and the reservoir subsequently fills and spills, the amount of water released from the reservoir earlier in the water year should not be charged to the (b)(2) account. If (b)(2) water is used to curtail CVP exports and the CVP responds by concurrently reducing reservoir releases that had been supporting some (or all) of the higher export rate, (b)(2) should only be charged for the difference.

Possible Approach: When (b)(2) was originally implemented, the Offset/Reset accounting rules were coded into CalSim-II. Although CalSim-II has undoubtedly changed in configuration since Offset/Reset was abandoned, most of

the former code should be usable in re-establishing the old accounting system in the current model.

Action: The "zero credit" treatment of the (b)(2) metric should be eliminated. When the (b)(2) step produces release and export metrics are less than the D-1485 "baseline" the (b)(2) account should be credited by the amount of the difference. ***Possible Approach:*** The current configuration of CalSim-II could be changed to accommodate this policy suggestion without major revision.

ALLOWING FOR EVALUATION OF ALTERNATIVE FLOW REGIMES

As stated at the very beginning of this report, the natural flow regime that characterizes the rivers of the Central Valley has been significantly modified by the water development that has taken place over the course of the past 100 years. While fully recreating this natural hydrology is not possible given the extent to which California relies on the installed hydraulic infrastructure, it is important to explore the degree to which system operations could be modified to mimic the natural hydrology within the context of the multiple objectives to which these operations respond. Under an environmentally preferred formulation, CalSim-II would be able to contribute to this sort of evaluation. CalSim-II already is able to handle environmental constraints related to minimum flow and acceptable rates of change in stream flow. Under an environmentally preferred formulation, this functionality should be used to investigate alternative regulatory regimes, such as full implementation of the AFRP recommendations. In addition, however, CalSim-II functionality should be added to accommodate the following potential changes in the flow regime that are of interest to the environmental community.

1. Period High Flow Events

Action:

All streams should have regularly occurring high flows that help restore the riparian forest, move and sort gravel, clean out silt from deep holes in the river bed, topple trees to create large woody debris in the stream and help maintain the naturally occurring conditions that depend on periodic high water. These high flow events need to recede at a rate consistent with the needs of newly germinating plants in the riparian forest. Appropriate high flow levels and the rate at which they recede will need to be determined for each stream. Current ecological understanding suggests that such events should occur once every five to ten years.

All the streams do not need to flood in the same year, though when storm induced floods do occur, the ramping down of the high water should be done at the rate needed for new riparian seedlings to become established. When natural flooding and receding doesn't occur, it should be scheduled and the flows accounted for in the long-term operation of upstream dams. Done in a coordinated manner, these flood flow releases can arrive in the Delta to meet the needs of the export pumps. For example, while some rivers are "flooding" in one winter, other rivers could be experience "man made" drought conditions. The flows into the delta are stable but the streams are benefiting from periodic, scheduled "floods".

2. Summer Low Flows

Action:

It is not natural to have high summer flows on the Sacramento, Feather, Yuba, American and other rivers in California's Central Valley. Presently these streams run high in the summer to meet water export demands in the Delta. The preferred condition should be a changed in how water is stored and delivered to the south via the Delta so that stream flows can drop in the summer and rise in the winter.

Until the infrastructure of Delta island reservoirs, groundwater conjunctive use reservoirs or local southern California water supplies are built, the best that can be done is an adaptive management plan of rotating low flows for these different streams. Both the volume and duration of low flows need to be evaluated for invasive weed reduction and restoration benefits.

The ability to investigate these components of the flow regime will require the development of new WRESL code. The actual design of software upgrades will be developed should the proposed functionality be included in a future environmentally preferred formulation of the CalSim-II model.

Conclusions

Having completed this environmental review of the CalSim-II model, we are left with the profound impression that it is not a tool that can – under its current formulation – fully address the legally required water management objectives. CalSim-II is, after all, a tool that has been designed to determine how best to operate the state's hydraulic infrastructure in ways that maximize the satisfaction of contractual demands. This reality is a result of both the history of water model development in California and a general analytical approach that has held sway for decades in the field of water resources planning and analysis. This approach holds that the environment is a constraint on system operations, not one of the objectives for which the system should be managed. In order to create a tool that can investigate water management innovations designed to comply with the law and restore the environment, it is not simply a matter of adjusting a few input parameters. Instead, a reformulation of the model along the lines described in this document is needed.

> CalSim-II holds that the environment is a constraint on system operations, not one of the objectives for which the system should be managed. In order to create a tool that can investigate water management innovations designed to comply with the law and restore the environment, it is not simply a matter of adjusting a few input parameters.

This philosophy of including the environment as an objective in water resources management is gaining credence around the world. Unfortunately, in California we cannot get to this point if we limit ourselves to the current version of CalSim-II. On the positive side, it is clear that no one views the current version of CalSim-II as the final and definitive water planning tool. An effort is underway to develop CalSim-III, which will respond to many of the critiques that have been offered about the model in recent months and years.

The conclusions of this report are offered to constructively contribute to this evolution. We feel that they will elevate, when implemented, aquatic ecosystem restoration to a place alongside of the other water management objectives in the system as is consistent with the imperatives of law and policy. A failure to respond to these critiques would demonstrate, on the other hand, that the water management community has little interest in viewing ecosystem restoration as more that a nettlesome constraint that has to be dealt with, preferably in the most minimal fashion. This would represent a division more profound than some varying professional opinions about the best way to model a complex water resource system.

attachment #10

Gerald Johns' Memo

Jan de Leeuw

October 23, 2005

These are brief comments on a Gerald Johns' memo to the Monterey Plus EIR Committee dd 90/22/05 re CALSIM II.

The argumentation in the memo is somewhat defensive and not always convincing. It is certainly true that the use of a model "to simulate actions in the system is valid and recognized practice". In fact, there is no alternative, because there is no physical copy of the system which can be used for experimentation. This does not imply, however, that the use of CALSIM II is "an acceptable and valuable analysis method". Such a conclusion certainly does not follow from the fact the models in general are useful, and asserting from the start that CALSIM II is valuable obviously begs the question if it is indeed valuable. The argument that DWR and other agencies have "consistently used CALSIM II" is not convincing either, unless it can be shown that this use has indeed led to better or more reliable predictions of supply than any of the available alternatives.

The memo does little more than summarizing the support materials that are available, without emphasizing that some of this material is quite critical of CALSIM II. The fact that CALSIM II is a cooperation between federal and state agencies may be important to federal and state bureaucrats, but it cannot be used as an argument in favor of the model. Similarly, the argument that using an optimization engine is what many other modeling

systems do is not a cogent argument, because it relies solely on authority and not on superior performance compared to other approaches. Intuitively, optimization engines do not seem to be very natural tools to model complex systems, because they assume all operators in the system are optimizers in possesion of perfect information. Also, by its very nature, if you maximize deliveries to purveyors, then of course you overestimate actual deliveries.

The memo adds the by now standard DWR disclaimer that "Traditional model calibration and verification process is difficult to apply to a planning model, such as CALSIM II, that simulates operations and water supplies at a fixed level of development". To me this has always seemed in appropriate testimonium paupertatis on the one hand, and a unconvincing attempt to have your cake and eat it too. Either CALSIM II is a model that describes the operations of SWP/CVP and is used to make predictions about future water supply to the purveyors, or it isn't. If it is, then it surely must be able to withstand traditional calibration and verification processes, because these are the only ways to assess its quality. If it is not such a model, then it clearly should not be used as such.

As I have said elsewhere, the main problems with CALSIM II is that it is only tested on a very limited set of realistic scenarios to assess its sensitivity, that it does not take the essentially stochastic nature of model inputs into account, that it optimizes deliveries instead of modeling actual deliveries, and that it has weak links between optimizations for successive time points. The actual implementation of CALSIM II has many additional problems. The documentation is virtually non-existent, the course of the program is not available, and the actual manipulations by DWR and its consultants to produce results from the program are shrouded with a mysterious layer of unassailable expertise.

In fact, at a recent CALSIM meeting in Sacramento, someone from the audience asked the chair of the peer review committee if anyone on the committee had ever tried to actually run the CALSIM II program. Somewhat surprisingly, the answer was no. For actual

not good

CALSIM II results the peer review relied on runs provided by DWR and its consultants. It is clear that such a strategy implies that what we studying is not just the actual computer program, but it is whatever goes on when the experts are producing their results, including possible non-documented tweaks and iterative attempts to "improve" the results of the runs. The CALSIM II provides much opportunity for such tweaking, for instance by relaxing "hard" to "soft" constraints.

I want to make this point perfectly clear, admittedly exaggerating (although I don't know by how much). There is no guarantee that the results in the SWP Delivery Reliability Report actually come from CALSIM II runs. The whole process of arriving at these results is not sufficiently transparent for others to be able to reproduce the results, and whenever that is the case a true peer review and true scientific scrutiny are not possible.

attachment #11

Mr. Gerald Johns
Deputy Director, DWR

October 2, 2005

Subject: Response to Director Johns' Letter of September 22, 2005 on CALSIM II

Dear Mr. Johns:

The letter was directed to the EIR committee but in fact it deals with comments generated by the plaintiff group of the committee. The comments we have generated over the past several months go to the technical validity of the model, CALSIM II, and because of its shortcomings its use as the tool in the Monterey Plus EIR. In your letter you make several assertions that are intended to respond to our comments but none really deal with the technical shortcomings of the model. As we have attempted to point out, the model contains fundamental errors in its construction that probably cannot be readily fixed. To continue to use this model in the EIR process will jeopardize the entire validity of the EIR. Accordingly, it is important that the Department undertake actions to address the vulnerability of the EIR.

You state that the model is an important tool to "study many technical and policy issues related to water supply reliability, environmental management and performance, water demands, economics, hydrology and climate, and regulatory compliance." In truth the model is not really specified to do these things and its construction is ill-suited to do them. Water supply reliability requires a model that has verified absolute accuracy, which can only be accomplished by calibration of this model to the historical record, which the Department has steadfastly refused to do.

Environmental management and performance would require that the model output provides measures that can be reasonably used to perform these tasks. In fact, the model treats the environmental issues as constraints buried in the hard code of the model and some of these constraints are of lower priority than water deliveries in the model. Furthermore, the constraints are based primarily on studies of the response of the environment in the Sacramento basin to conditions and project operations prior to the Monterey Amendments. Because this uncalibrated model now predicts that average future deliveries can be increased by 50% over pre-Monterey operations, a review of those old constraints is absolutely required. The current conditions of ecological collapse in the Delta demand it. But this model is exceedingly cumbersome to use for this purpose. What new constraints should be offered? Shouldn't we be going back to the State Water Resources Control Board for review? These are questions that need to be answered before an EIR is ever published.

Water demands are not treated by this model save for the users in the Sacramento Valley, most of who are not SWP beneficiaries. In fact, the model assumes that all SWP contractors except MWD and KCWA will request full Table A amounts from now on. Furthermore, as we have pointed out in our previous comments, at least one of those demands is totally unrealistic and that is the case of San Luis Obispo County for which the model assumes 25,000 acre-feet as its annual request when in fact it has SWP pipeline capacity for only 4800 acre-feet. Other demands can also be argued to be without any merit. One must conclude that the model is not being used to "study ...water demands"

when in fact demands are taken as fixed inputs to the model without any critical evaluation of the capabilities of the contractors to take such amounts.

Similar arguments can be raised as to how much the model is used to study "regional hydrology." As with demands, the most important hydrologic input is the historical record of major stream runoff into the Central Valley. If this hydrologic record had been studied, one would have immediately found that its statistical makeup is very complex and that the simple tacit assumptions built in to the model regarding that makeup are just plain wrong. The statistical flaws impact both the interpretation given to the model's output and to the fundamental specification of indices used in the model. These flaws are of such degree that both the model and the indices need to be re-specified. The model as it stands is basically useless as a tool for EIR or reliability studies.

In general, the model is ill-specified for the uses to which it is being put in the Monterey Plus EIR. A correctly specified model would begin with environmental variables as dependent variables rather than constraints. In other words, we need a model in which one can input hydrology and demands and retrieve as output changes in the environment. CALSIM II does the exact opposite. In fact, it is very reasonable to question a model that is designed to maximize exports as in any way suitable to study environmental impacts.

Your assertion that CALSIM II is an accepted tool for use in environmental impact analysis and planning is not warranted. The Peer Review Committee strongly recommended that CALSIM II be calibrated properly if it is to be used for objective measures of system performance. Both reliability assessment and environmental impact analysis both depend on objective measures.

And again, I must take issue with your general assertions of "good faith" efforts on the part of DWR staff. The Department has been asked on several occasions beginning with the settlement negotiations on through the EIR preparation to perform calibration of the model. The Department has stonewalled on this request for close to 5 years now.

As to your comments on how the Department has made its choice to use this model after receiving comments from many forums, again there has been a total reluctance to join the technical issues of the model's flaws. We made very specific comments on the draft Reliability report questioning the statistical use of the output data. There was no response from anyone in DWR to support its particular use of statistics. In general, the Department has never attempted to join the issue of the statistical flaws in the model, continuing to dismiss criticisms to that effect with broad statements such as you make here. We must consider these broad statements to be totally inadequate as a response.

You refer to the Peer Review Committee's report to substantiate your general claims for this model. However, you should realize that the Peer Review Panel made its comments about optimization models and their suitability as a general approach. Their more specific claims about the use of CALSIM II were not supportive. And we must remind the Department that the Peer Review Panel was asked to review a model without any specific application in mind nor without any model specification. In fact, we have not seen a model specification against which we can validate the model's performance. A model specification is an essential step in any model development. We are sure that if the original model specification had called for the ability to perform environmental impact

analyses and delivery reliability assessments it would have been structured in a completely different fashion. It certainly would have called for model calibration and that requirement would have led to a model whose structure would readily allow calibration. We have been continually told that this model can't be calibrated, which we consider nonsense.

With regard to the Department's report where they outline their continuing effort to establish trust in and credibility for the model, we regard that as nothing but "spin" given the Department's stonewalling on critical technical issues that have more to do with developing "trust and credibility".

Finally, if your letter was intended to be a response to technical comments, we regard it as totally unresponsive.

Sincerely,

Arve R. Sjovold
Plaintiff Citizens Planning
Association Representative
To The EIR Committee

attachment #12

SOME INSIGHTS ON WATER DELIVERIES TO SETTLEMENT CONTRACTORS

By: Arve R. Sjovold
October 24, 2004

In the course of reviewing the use of specific indices in the CALSIM II model it was brought to my attention that the Feather River Settlement Contractors agreed in the contracts to receive 50% cutbacks in years designated "drought years." The 50% cutback is against their total demand according to the research conducted by Jeffrey Payne. What is interesting about this particular requirement is what it does to the rights of the Settlement Contractors when viewed from the perspective of the Monterey Amendments and the Environmental Water Account (EVA).

The feature of the Monterey Amendments that is of interest is the removal from the master contracts of provision 18 (a), the provision that called for agricultural cutbacks first in time of drought. The primary beneficiary of this removal has been Kern County Water Agency (KCWA), which now takes all the water it can get to store in the Kern Water Bank to be sold back to the EWA. Clearly, if the Settlement Contractors did not take cuts in drought years, as KCWA no longer has to do, there would be less water going south, especially to KCWA. In fact, the settlement contractors could then be the benefactors for the EWA and could also be the beneficiaries of the payouts from the EWA. Given the construct of the EWA, this only seems fair since it is water from the watershed of origin that is at issue and should by senior right belong to the Settlement Contractors.

There is also a factor of fairness involved here. When the SWP and Oroville Dam were authorized is when these settlement contracts were executed. At that time, the SWP contracts included the 18 (a) provision, so one could fairly state that SWP ag contractors and settlement contractors were being treated equally. Now that Monterey has attempted to do away the ag first provision in the SWP contracts, it only seems fair at a minimum that the same provision be deleted from the settlement contracts.

ON THE ADEQUACY OF CALSIM II FOR ENVIRONMENTAL IMPACT ANALYSIS AND SWP RELIABILITY ANALYSIS

attachment #13

By: Arve R. Sjovold

August 12, 2004

Introduction:

The matter of application of CALSIM II to a variety of analyses has been questioned by many in water resources analyses, most notably by the scientific peer review team recently convened by the California Bay Delta Authority Science Program, Association of Bay Governments whose comments have been documented in a report dated December 4, 2003. In that report the peer review panel made many comments on the adequacy of CALSIM II which have yet to be acted upon. Several of the comments are directly related to the adequacy of CALSIM II to address the applications of environmental impact analyses and delivery reliability analyses of the SWP. The peer review was broad in reach and was not directed toward any specific application. However, its comments regarding the applications cited above are very pertinent now that the Department of Water Resources (DWR) is moving ahead to use this model for purposes of assessing the environmental impacts of the Monterey Amendments to the SWP contracts and because the Castaic Lake Water Agency (CLWA) is also using the same model outputs for justifying its Urban Water Management Plan and a controversial action to claim as lawful a 41,000 acre-foot transfer of SWP entitlement from the Kern County Water Agency.

Because DWR has not acted on any of the peer review recommendations regarding deficiencies in CALSIM II, it is important that a clear statement be made regarding CALSIM II's adequacy to pursue both the environmental impact analysis of the Monterey Amendments and the CLWA proposed action. Because both environmental impact analysis and delivery reliability analyses require some measure of accuracy in their assessments it is vitally important to assess the accuracy of the CALSIM II calculated estimates. We and the peer review panel agree that calibration of the model is paramount if we are to make any confident statements of accuracy for this model. To date DWR has refused to do a timely calibration of the model even though they have been asked on many occasions over the past several years to do so. It is disingenuous on their part now to move ahead with production runs from this model arguing that they have insufficient time to do a proper calibration. Nevertheless, there are some definitive statements that can be made at this time based on the information made available by DWR in various documents.

Accuracy

Both the preliminary outputs for the environmental impact analysis and the documented outputs from the reliability assessment performed by DWR show levels of export from the Delta that average 50% higher than any estimates of actual average

exports evident to date. These predicted levels of export are not qualified by any statements of how accurate they may be based on comparisons to the historical record. In responses to comments received on their final report on delivery reliability they did include some comparisons to predicted and actual deliveries during the most recent drought (1987-1992). That report also reported actual delivery history through 2003. Although the comparison during the drought seems quite good, that same comparison shows that the SWP could not come close to requested deliveries (Demands) over that period. Additional information supplied by DWR in the appendices of that report also shows that even after the drought, actual deliveries showed large shortfalls below requests. Table 1 shows the data extracted from the DWR reports. (These data are for Table A requests and Table A deliveries.)

Table 1

COMPARISONS OF ACTUAL DELIVERIES AND REQUESTED DEMANDS (maf/yr) 1987 to 2002

Year	Requested Demands	Actual Deliveries
1987	2.7	2.14
1988	2.6	2.32
1989	3.0	2.71
1990	3.1	2.45
1991	3.5	0.55
1992	3.6	1.38
1993	2.75	2.10
1994	2.7	1.75
1995	3.15	1.87
1996	2.7	2.21
1997	3.0	2.29
1998	3.2	1.62
1999	3.2	2.52
2000	3.6	2.71
2001	4.05	1.39
2002	3.9	2.52

It is apparent that throughout this period the SWP had difficulty meeting requests. It is significant to note that the last several years bracket the year 2001, which is one of the parametric levels of development for which CALSIM II calculates expected deliveries. It is also noteworthy that the average delivery for the last 6 years in this series is virtually the same as the first 6 years, the acknowledged period of the drought. The series shows a trend whereby the requests slowly increase over time but in the last 6 years of the series the contractor requests are virtually at the same level as that parametrized for the CALSIM II 2001 run. Accordingly, it is difficult to see how DWR can state that the primary reason that past deliveries are not as high as the model now predicts for the 2001

run is "..that the contractors did not ask for enough in the past." These data clearly show that the SWP has difficulty averaging more than 2.0 maf independent of request levels. It also demonstrates why it is important to calibrate this model so that we can deduce why it fails to accurately reproduce the historical record by any ordinary accounting. We may conclude that the CALSIM II model, absent calibration, is inadequate for any application relying on the accuracy of its calculations. One may state that, based on the data record of requests and deliveries, that the CALSIM II model overestimates deliveries by at least 50% on average. We can further state that the SWP based on the history of actual deliveries can not be relied upon for more than 2.0 maf of total delivery, approximately 48% of Table A entitlements. The record also clearly shows that in the depths of a prolonged 6 year drought that the average reliable delivery is not more than 38%(See my analysis of the statistical analysis of the CALSIM II calculations; "ANALYSIS OF SWP RELIABILITY OF DELIVERY", November 11, 2003.) We may further state that without a peer reviewed calibration and appropriate documentation, that CALSIM II cannot be relied upon for the accuracy of its calculations. These are all important conclusions regarding the adequacy of CALSIM II to support environmental impact analysis or for estimating SWP delivery reliability.

We also note that the charts presenting the results of the CALSIM II runs in support of the Monterey EIR seem to predict even higher deliveries overall than was shown in the DWR reliability report for ostensibly the same conditions and constraints. The reliability report presents 73 year average deliveries of approximately 3.1 to 3.2 maf for the 2020 scenario while the more recent runs are reporting 3.4 maf for the same scenario. A difference of this amount needs to be explained as to where the additional water is coming from.

Another factor affecting the accuracy and utility of CALSIM II calculations is the reconciliation of its optimal outputs with feasible SWP operational scenarios. It is a characteristic of an optimization methodology as used in CALSIM II to substitute the optimization algorithm for the detailed simulation of all the decision operations that properly depict the real system. In the particular optimization used in CALSIM II the set of solution weights is the surrogate for all the decision criteria that would ordinarily be simulated. In order to render the results of the optimization calculations useful, the set of solution weights must be reduced to a realistic, feasible set of decision criteria that can be implemented. Otherwise, there is no assurance that the optimization results are realizable.

Environmental Impact analysis

DWR has recently presented draft presentations of CALSIM II outputs in support of environmental impact analysis for the Monterey Amendments EIR. These calculations are performed on the same basis as those used in the SWP reliability of delivery analysis in that the model is not calibrated and the methodology is the same. However, the impact analysis proceeds on assumptions that may or may not be applied to previous calculations for reliability delivery. Most important, beyond the fundamental deficiency of an uncalibrated model, are the assumptions made on the priority of exports.

One of the fundamental scenarios in effect mandated by the Court of Appeals is to study the "no project alternative." This is the scenario where it is envisioned that DWR invokes Article 18(b) to address the chronic deficiency to deliver full entitlement

amounts as articulated in the SWP contracts. If Article 18(b) is invoked it requires that DWR reduce uniformly the stated Table A entitlements of all the contractors down to a level that reasonably conforms to the ability of the project to deliver those entitlements reliably. The data in Table 1 above suggest that this new level of aggregate entitlement should be about 2.0 maf or less compared to the original 4.23 maf of the original contracts. This represents a uniform lowering of contractor entitlements to approximately 47%. If DWR were to take this action, it would raise the question of how water exports would be managed when there is more water coming into the Delta than would seem necessary to meet entitlements, the so-called "surplus" water.

The calculations performed by DWR with CALSIM II assume that all the water that arrives in the Delta is available solely to the projects after meeting regulatory requirements in the Delta and after providing for Delta uses. The regulatory requirements that are assumed are those prevailing today. Therefore, the calculations simply treat the surplus water created by invoking Article 18(b) as water to be freely exported as before. In consequence, the amounts shown in the preliminary runs show nearly similar totals to those without invoking Article 18(b). The only significant difference between runs with and without Article 18(b) invoked is the label put on the water exported; the amounts are the same.

There are several things wrong with this assumption regarding surplus water. If indeed there is water that is surplus to regulatory constraints it does not necessarily mean that it is in the same entitlement category as entitlement water (i.e. Table A water). This is especially true when one considers that present operations have not redressed nor restored the Delta environment. If water is surplus beyond entitlement water its use to redress environmental damage in the Delta must be given priority over exports as surplus. At the very least, CALFED should not be required to pay for water to put in the environmental water account to offset costs to would-be entitlement exports when the SWP is mandated to stop pumping for protection of endangered species. In fact, export of so-called surplus water should be accorded lower priority than any watershed of origin claims. In other words, surplus water should be dedicated to protection of the environment in the watershed of origin before consideration is given to export to what are recognized as junior water rights holders. We cannot accept that export water has superior claim to water originating in the Sacramento and Trinity watersheds in analyzing environmental impacts of this project. The environmental impact analysis must consider the use of surplus water in fashioning an environmentally superior alternative to the assumed no-project alternative used in developing CALSIM II estimates. Furthermore, we must acknowledge that regulatory constraints established on the basis of existing operations, especially when considering the adversarial nature of the process of water rights hearings, cannot be considered as fixed limits on future operations that on their face propose to export at least 50% more water than the conditions that led to those constraints. Calculations that purport to show that 50% more water can be exported than present operations must be subjected to careful scrutiny as to the likelihood of even more damage to the environment than has already been sustained. We cannot simply assume that the existing constraints are satisfactory to de-limit environmental impacts in the face of increased exports. The calculations must reflect real considerations of more stringent constraints with increasing exports if they are to be used for environmental impact assessments.

In previous meetings of the EIR sub-committee on modeling, flow charts of the simulation network that is modeled were presented. At those meetings objections were raised concerning the lack of any fidelity in network representation for south-of-Delta operations. This especially concerns operations of the San Joaquin and Stanislaus rivers as well as the operations of the Kern Water Bank. We have since learned that detailed networks for the San Joaquin and Stanislaus systems have indeed been developed for other analyses. We see no reason why this detail should not be included in the CALSIM II model used for the Monterey Amendments EIR. We also note that even in this additional detail, no distinction is made between exports of entitlement and surplus water as far as priority of uses in the model calculations. We request that in all CALSIM II simulated systems in either the Sacramento or San Joaquin valleys, the simulations carefully reflect that surplus water flows, where ever they may occur, should be represented as lower priority than water shed of origin uses, whether in-stream or diversions for beneficial use.

We have also learned that SWP and CVP contractor demand functions are used on their face to establish the amounts of exports that guide the optimization of the CALSIM II model, while the settlement contractors in the area-of-origin are modeled by simulation of actual applied water requirements based on land use. Since the water rights of export are necessarily junior to those of the settlement contractors we see no reason why export contractor demand, at a minimum, should not be modeled to the same degree as the settlement contractors. In fact, the modeling of settlement contractor demands based on land uses in the Sacramento and Feather River areas show that these diversions are approximately 1maf less than the maximum under the settlement contracts. This means that export amounts calculated by CALSIM II include in effect a "borrowing" of water that by right belongs to settlement contractors. Is it proper to include such water as entitlement water to exporters when it may in fact be taken by senior rights holders at some unspecified time?

We also note the export demand functions are assumed at Table A levels for all but the two largest contractors, MWD and KCWA, even though most of the contractors do not have sufficient storage to balance wet year deliveries with dry year deliveries. (See my analysis of the reliability report previously cited.) We also note that the SWP contractor demand functions for each contractor must be developed consistent with the ability of the contractor to accept SWP water when it is available. In many cases, without equalizing storage, a contractor cannot even accept his full annual entitlement because of capacity constraints. Our calculations on this limitation could limit the effective delivery of entitlement water to about 60% of the full Table A annual entitlement in some cases. The degree to which a specified contractor can avail himself of SWP deliveries depends critically on how he structures his priority of use of his different sources of supply. To maximize SWP entitlement deliveries, a contractor may often have to forego the use of a cheaper, local source and instead pay a little more to secure a higher reliability of delivery of SWP water. To our knowledge none of these considerations have been factored in to the assumptions of contractor demand and the preliminary calculations produced by CALSIM II cannot be taken as realistic.

Reliability of Delivery Analysis

For reliability of SWP deliveries it should be clear that only deliveries against Table A amounts can be accounted. Since the majority of SWP deliveries are designated as M&I, those uses, which entail fixed structures dependent on firm water supplies, cannot be tied to speculative deliveries associated with so-called "surplus" water. The calculations supplied by CALSIM II to date do not distinguish the importance of the delivery categories to the reckoning of reliability of supply. Even those contractors that have some level of equalizing storage by which they can store surplus wet year deliveries to be used in times of drought should have to demonstrate and implement a plan to use the deliveries in that way before any surplus deliveries can be accounted as firm supply, and the amounts of surplus delivery to be expected must meet all the requirements for environmental protection in the watersheds of origin as cited above.

We must also state that DWR's continued use of frequency charts to present the results of its calculations on reliability of delivery is unwarranted. There is no statistical basis presented by DWR to show why drought deliveries should be lumped with normal and wet year deliveries in a single frequency diagram. (Again see my analysis of delivery reliability cited above.) This flagrant misuse of statistics is now being seized upon by local planning authorities who adopt SWP reliabilities that cannot in fact be sustained. The consequence is that in all probability local land use plans are being based on erroneously high deliveries that are the epitome of "paper water." Irrespective of the accuracy and deficiencies of CALSIM II, DWR must provide more robust statistical analyses of CALSIM II outputs if they are to be useful to anyone.

The assessment of SWP delivery reliability must depend on calculations that meet stringent requirements of accuracy and proper statistical practice. Neither requirement is presently met by the CALSIM II model.

Conclusions

Because of the necessity of having accurate estimates of SWP deliveries under the scenarios cast for the EIR impact analyses, it is absolutely required that this model be calibrated and peer reviewed for that calibration. Based on the record to date of SWP operations there is no reason to believe that the CALSIM II calculations have any utility for EIR impact analyses.

The scenarios that have been cast must be reformulated to consider uses of so-called "surplus" water for environmental restorations and enhancement in the water sheds of origin. It cannot be taken as given that water identified by the SWP contracts as surplus to whatever level of Table A entitlements is free to be exported solely to the contractors.

The calculations of CALSIM II must be reported in more detail to deduce environmental impacts. At a minimum, estimates for delivery to each contractor must be reported by month and arrayed against each contractor's monthly requests. DWR must ascertain the validity of each contractor's water supply plan insofar as the use of SWP water is involved. Of particular concern is the availability of equalizing storage in each contractor's service area. This is to assure that no contractor is taking water for beneficial use that can be claimed by a superior right holder in the watersheds of origin.

DWR must provide for a more thorough and robust statistical analysis of CALSIM II's calculated outputs. The present portrayals are simply improper and not

deserving of the effort that has gone in to generating the outputs. The present outputs cannot be used to make any useful estimates of reliability of delivery.

DWR must show that the optimization results represent a feasible solution of realistic decision criteria by which the project can be operated.

attachment #14

Emissions pathways, climate change, and impacts on California

Katharine Hayhoe[a,b], Daniel Cayan[c], Christopher B. Field[d], Peter C. Frumhoff[e], Edwin P. Maurer[f], Norman L. M
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Contributed by Christopher B. Field, June 23, 2004

The magnitude of future climate change depends substantially on the greenhouse gas emission pathways we choose. Here we explore the implications of the highest and lowest Intergovernmental Panel on Climate Change emissions pathways for climate change and associated impacts in California. Based on climate projections from two state-of-the-art climate models with low and medium sensitivity (Parallel Climate Model and Hadley Centre Climate Model, version 3, respectively), we find that annual temperature increases nearly double from the lower B1 to the higher A1fi emissions scenario before 2100. Three of four simulations also show greater increases in summer temperatures as compared with winter. Extreme heat and the associated impacts on a range of temperature-sensitive sectors are substantially greater under the higher emissions scenario, with some interscenario differences apparent before midcentury. By the end of the century under the B1 scenario, heatwaves and extreme heat in Los Angeles quadruple in frequency while heat-related mortality increases two to three times; alpine/subalpine forests are reduced by 50–75%; and Sierra snowpack is reduced 30–70%. Under A1fi, heatwaves in Los Angeles are six to eight times more frequent, with heat-related excess mortality increasing five to seven times; alpine/subalpine forests are reduced by 75–90%; and snowpack declines 73–90%, with cascading impacts on runoff and streamflow that, combined with projected modest declines in winter precipitation, could fundamentally disrupt California's water rights system. Although interscenario differences in climate impacts and costs of adaptation emerge mainly in the second half of the century, they are strongly dependent on emissions from preceding decades.

California, with its diverse range of climate zones, limited water supply, and economic dependence on climate-sensitive industries such as agriculture, provides a challenging test case to evaluate impacts of regional-scale climate change under alternative emissions pathways. As characterized by the Intergovernmental Panel on Climate Change, demographic, socioeconomic, and technological assumptions underlying long-term emissions scenarios vary widely (1). Previous studies have not systematically examined the difference between projected regional-scale changes in climate and associated impacts across scenarios. Nevertheless, such information is essential to evaluate the potential for and costs of adaptation associated with alternative emissions futures and to inform mitigation policies (2).

Here, we examine a range of potential climate futures that represent uncertainties in both the physical sensitivity of current climate models and divergent greenhouse gas emissions pathways. Two global climate models, the low-sensitivity National Center for Atmospheric Research/Department of Energy Parallel Climate Model (PCM) (3) and the medium-sensitivity U.K. Met Office Hadley Centre Climate Model, version 3 (HadCM3), model (4, 5) are used to calculate climate change resulting from the SRES (Special Report on Emission Scenarios) B1 (lower) and A1fi (higher) emissions scenarios (1). These scenarios bracket a large part of the range of Intergovernmental Panel on Climate Change nonintervention emissions futures with atmospheric concentrations of CO_2 reaching ≈550 ppm (B1) and ≈970 ppm (A1fi) by 2100 (see *Emissions Scenarios* in *Supporting Text*, which is published as supporting information on the PNAS web site). Although the SRES scenarios do not explicitly assume any specific climate mitigation policies, they do serve as useful proxies for assessing the outcome of emissions pathways that could result from different emissions reduction policies. The scenarios at the lower end of the SRES family are comparable to emissions pathways that could be achieved by relatively aggressive emissions reduction policies, whereas those at the higher end are comparable to emissions pathways that would be more likely to occur in the absence of such policies.

Climate Projections

Downscaling Methods. For hydrological and agricultural analyses, HadCM3 and PCM output was statistically downscaled to a 1/8° grid (≈150 km^2) (6) and to individual weather stations (7) for analyses of temperature and precipitation extremes and health impacts. Downscaling to the 1/8° grid used an empirical statistical technique that maps the probability density functions for modelled monthly precipitation and temperature for the climatological period (1961–1990) onto those of gridded historical observed data, so the mean and variability of observations are reproduced by the climate model data. The bias correction and spatial disaggregation technique is one originally developed for adjusting General Circulation Model output for long-range streamflow forecasting (6), later adapted for use in studies examining the hydrologic impacts of climate change (8), and compares favorably to different statistical and dynamic downscaling techniques (9) in the context of hydrologic impact studies.

Station-level downscaling for analyses of temperature and precipitation extremes and health impacts used a deterministic method in which grid-cell values of temperatures and precipi-

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Abbreviations: DJF, December, January, February; HadCM3, Hadley Centre Climate Model, version 3; JJA, June, July, August; PCM, Parallel Climate Model; SRES, Special Report on Emission Scenarios; SWE, snow water equivalent.

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Table 1. Summary of midcentury (2020–2049) and end-of-century (2070–2099) climate and impact projections for the HadCM3 and PCM B1 and A1fi scenarios

			2020–2049				2070–2099			
			PCM		HadCM3		PCM		HadCM3	
	Units	1961–1990	B1	A1fi	B1	A1fi	B1	A1fi	B1	A1fi
Change in statewide avg temperatures										
Annual	°C	15.0	1.35	1.5	1.6	2.0	2.3	3.8	3.3	5.8
Summer (JJA)	°C	22.8	1.2	1.4	2.2	3.1	2.15	4.1	4.6	8.3
Winter (DJF)	°C	7.6	1.3	1.2	1.4	1.45	2.15	3.0	2.3	4.0
Change in statewide avg precipitation										
Annual	mm	544	−37	−51	+6	−70	+38	−91	−117	−157
Summer (JJA)	mm	20	−3	+2	−1	−7	+4	−46	−5	−1
Winter (DJF)	mm	269	−45	−55	+4	−44	+13	−13	−79	−92
Sea level rise	cm	—	8.7	9.5	11.6	12.7	19.2	28.8	26.8	40.9
Heatwave days										
Los Angeles	Days	12	28	35	24	36	44	76	47	95
Sacramento	Days	58	91	101	93	104	109	134	115	138
Fresno	Days	92	113	120	111	116	126	147	126	149
El Centro	Days	162	185	185	176	180	191	213	197	218
Length of heatwave season*	Days	115	135	142	132	141	149	178	162	204
Excess mortality for Los Angeles†										
Without acclimatization	avg no. of deaths/yr	—	—	—	—	—	394	948	667	1,429
With acclimatization	avg no. of deaths/yr	165	—	—	—	—	319	790	551	1,182
Change in April 1 snowpack SWE										
1,000–2,000 m elevation	%	3.6 km^3	−60	−56	−58	−66	−65	−95	−87	−97
2,000–3,000 m elevation	%	6.5 km^3	−34	−34	−24	−36	−22	−73	−75	−93
3,000–4,000 m elevation	%	2.3 km^3	−11	−15	4	−16	15	−33	−48	−68
All elevations	%	12.4 km^3	−38	−37	−26	−40	−29	−73	−72	−89
Change in annual reservoir inflow‡										
Total	%	21.7 km^3	−18	−22	5	−10	12	−29	−24	−30
Northern Sierra	%	15.2 km^3	−19	−22	3	−9	9	−29	−20	−24
Southern Sierra	%	6.5 km^3	−16	−23	10	−14	17	−30	−33	−43
Change in April–June reservoir inflow‡										
Total	%	9.1 km^3	−20	−24	−11	−19	−1	−46	−41	−54
Northern Sierra	%	5.5 km^3	−21	−24	−16	−19	−6	−45	−34	−47
Southern Sierra	%	3.6 km^3	−18	−24	−2	−19	5	−47	−52	−65
Change water year flow centroid‡										
Total	Days	03/26	0	2	−15	−7	−7	−14	−23	−32
Northern Sierra	Days	03/13	0	3	−16	−5	−3	−11	−18	−24
Southern Sierra	Days	05/01	−10	−7	−19	−12	−22	−34	−34	−43

avg, average; JJA, June, July, August; DJF, December, January, February; SWE, snow water equivalent.
*The number of days between the beginning of the year's first and end of the year's last heatwave.
†Reference period is 1990–1999, and projections are for the period 2090–2099.
‡Results are for inflows to seven major dams and reservoirs in the Sacramento/San Joaquin water system, including three in the Northern Sierra (Shasta, Oroville, and Folsom) and four in the Southern Sierra (New Melones, New Don Pedro, Lake McClure, and Pine Flat).

tation from the reference period were rescaled by simple monthly regression relations to ensure that the overall probability distributions of the simulated daily values closely approximated the observed probability distributions at selected long-term weather stations (7). The same regression relations were then applied to future simulations, such that rescaled values share the weather statistics observed at the selected stations. At the daily scales addressed by this method, the need to extrapolate beyond the range of the historically observed parts of the probability distributions was rare even in the future simulations (typically <1% of the future days) because most of the climate changes involve more frequent warm days than actual truly warmer-than-ever-observed days (7).

Except where otherwise noted, we present projected climate anomalies and impacts averaged over 2020–2049 (with a midpoint of 2035) and 2070–2099 (here designated as end-of-century, with a midpoint of 2085), relative to a 1961–1990 reference period.

Temperature. All simulations show increases in annual average temperature before midcentury that are slightly greater under the higher A1fi emissions scenario (see Fig. 4, which is published as supporting information on the PNAS web site). By end-of-century, projected temperature increases under A1fi are nearly twice those under B1, with the more sensitive HadCM3 model producing larger absolute changes (Table 1). Downscaled seasonal mean temperature projections (10) show consistent spatial patterns across California, with lesser warming along the southwest coast and increasing warming to the north and northeast (Fig. 1). Statewide, the range in projected average temperature increases is higher than previously reported (11–14), particularly for summer temperature increases that are equal to or greater than increases in winter temperatures.

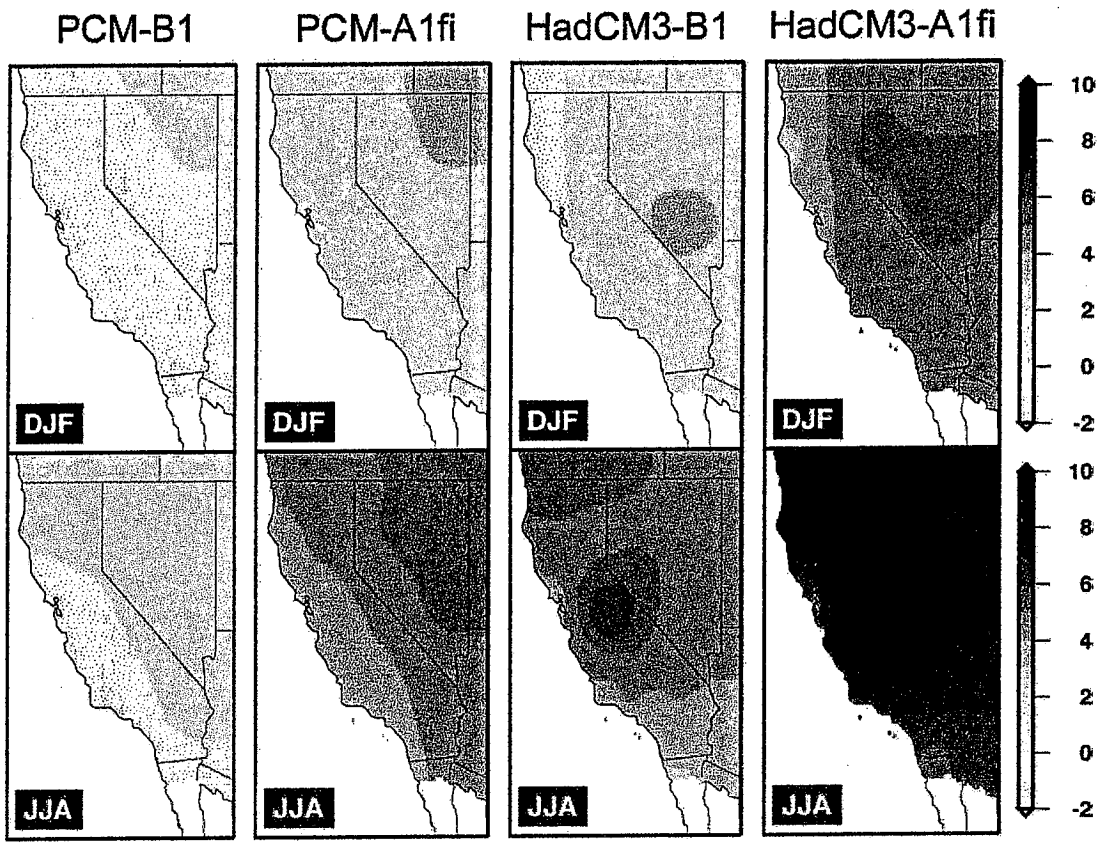

Fig. 1. Downscaled winter (DJF) and summer (JJA) temperature change (°C) for 2070–2099, relative to 1961–1990 for a 1/8° grid. Statewide, SRES B1 to A1fi winter temperature projections for the end of the century are 2.2–3°C and 2.3–4°C for PCM and HadCM3, respectively, compared with previous projections of 1.2–2.5°C and 3–3.5°C for PCM and HadCM2, respectively. End-of-century B1 to A1fi summer temperature projections are 2.2–4°C and 4.6–8.3°C for PCM and HadCM3, respectively, compared with previous projections of 1.3–3°C and 3–4°C for PCM and HadCM2, respectively (11–14).

Precipitation. Precipitation shows a tendency toward slight decreases in the second half of the century with no obvious interscenario differences in magnitude or frequency (see Figs. 5–10, which are published as supporting information on the PNAS web site). Three of four simulations project winter decreases of −15% to −30%, with reductions concentrated in the Central Valley and along the north Pacific Coast. Only PCM B1 projects slight increases (≈7%) by the end of the century (Table 1). These results differ from previous projections showing precipitation increases of 75–200% by 2100 (11–13), but they are consistent with recent PCM-based midrange projections (14, 15). The larger-scale pattern of rainfall over North America is more uniform across scenarios, showing an area of decreased (or lesser increase in) precipitation over California that contrasts with increases further up the coast (see Fig. 11, which is published as supporting information on the PNAS web site). Because interdecadal variability often dominates precipitation over California, projected changes in climate and impacts associated with the direct effects of temperature should be considered more robust than those determined by interactions between temperature and precipitation or precipitation alone.

Extreme Heat and Heat-Related Mortality

Temperature extremes increase in both frequency and magnitude under all simulations, with the most dramatic increases occurring under the A1fi scenario. Changes in local temperature extremes were evaluated based on exceedance probability analyses, by using the distribution of daily maximum temperatures downscaled to representative locations (16). Exceedance probabilities define a given temperature for which the probability exists that X% of days throughout the year will fall below that temperature (i.e., if the 35°C exceedance probability averages 95% for the period 2070–2099, this means that an average of 95% or ≈347 days per year are likely to lie below 35°C). For the four locations examined for extreme heat occurrence (Los Angeles, Sacramento, Fresno, and Shasta Dam), mean and maximum temperatures occurring 50% and 5% of the year increase by 1.5–5°C under B1 and 3.5–9°C under A1fi by the end of the century. Extreme temperatures experienced an average of 5% of the year during the historical period are also projected to increase in frequency, accounting for 12–19% (B1) and 20–30% (A1fi) of days annually by 2070–2099 (see Fig. 12, which is published as supporting information on the PNAS web site).

The annual number of days classified as heatwave conditions (3 or more consecutive days with temperature above 32°C) increases under all simulations, with more heatwave days under A1fi before midcentury (see Fig. 13, which is published as supporting information on the PNAS web site). Among the four locations analyzed, increases and interscenario differences are proportionally greatest for Los Angeles, a location that currently experiences relatively few heatwaves. By the end of the century, the number of heatwave days in Los Angeles increases four times under B1, and six to eight times under A1fi. Statewide, the length of the heatwave season increases by 5–7 weeks under B1 and by 9–13 weeks under A1fi by the end of this century, with interscenario differences emerging by midcentury (Table 1; see also Fig. 14, which is published information on the PNAS web site).

The connection between extreme heat and summer excess mortality is well established (17). Heat-related mortality estimates for the Los Angeles metropolitan area were determined

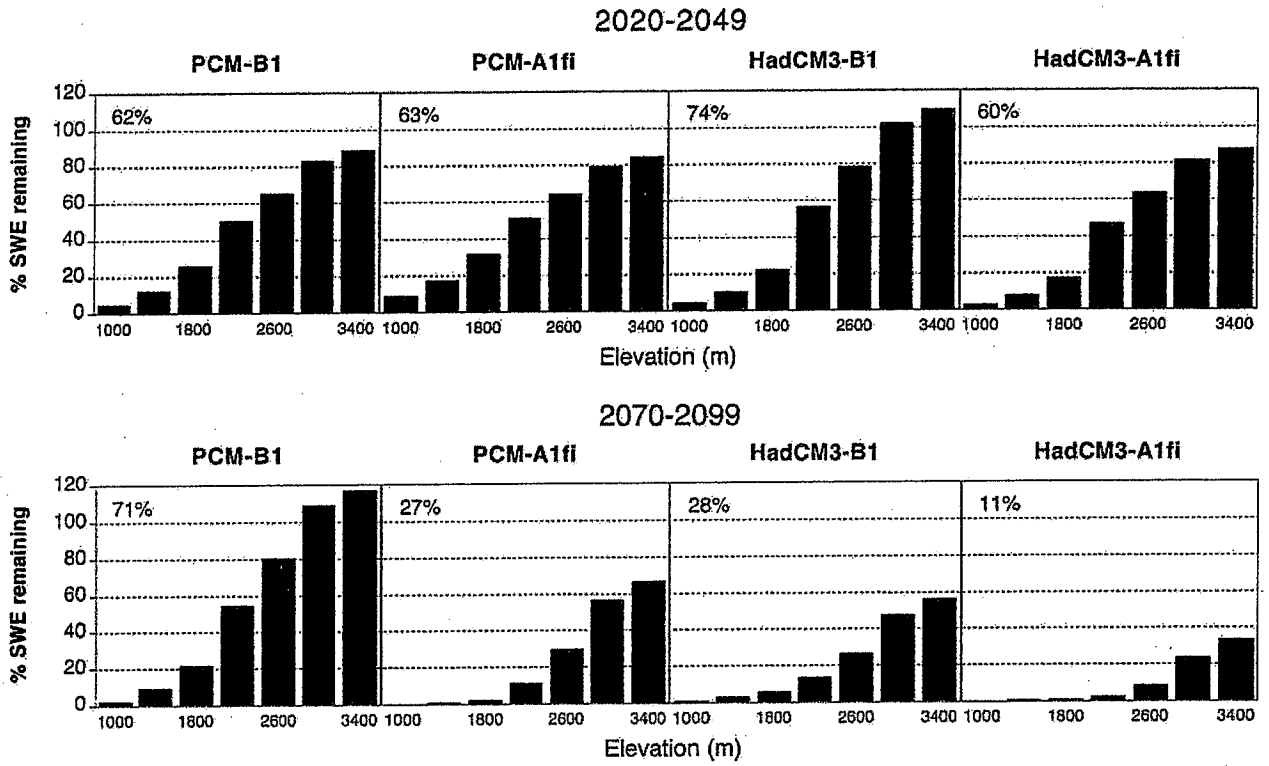

Fig. 2. Average snowpack SWE for 2020–2049 and 2070–2099 expressed as a percent of the average for the reference period 1961–1990 for the Sierra Nevada region draining into the Sacramento–San Joaquin river system. Total SWE losses by the end of the century range from 29–72% for the B1 scenario to 73–89% for the A1fi scenario. Losses are greatest at elevations below 3,000 m, ranging from 37–79% for B1 to 81–94% for A1fi by the end of the century. Increases in high elevation SWE for midcentury HadCM3 B1 and end-of-century PCM B1 runs result from increased winter precipitation in these simulations.

by threshold meteorological conditions beyond which mortality tends to increase. An algorithm was developed to determine the primary environmental factors (including maximum apparent temperature, number of consecutive days above the threshold apparent temperature, and time of year) that explain variability in excess mortality for all days with apparent maximum temperatures at or above the derived daily threshold apparent temperature (18) value of 34°C (see *Heat-Related Mortality* in *Supporting Text*). Estimates do not account for changes in population or demographic structure.

From a baseline of ≈165 excess deaths during the 1990s, heat-related mortality in Los Angeles is projected to increase by about two to three times under B1 and five to seven times under A1fi by the 2090s if acclimatization is taken into account (see *Heat-Related Mortality* in *Supporting Text*). Without acclimatization, these estimates are about 20–25% higher (Table 1). Actual impacts may be greater or lesser depending in part on demographic changes and societal decisions affecting preparedness, health care, and urban design. Individuals likely to be most affected include elderly, children, the economically disadvantaged, and those who are already ill (19, 20).

Impacts on Snowpack, Runoff, and Water Supply

Rising temperatures, exacerbated in some simulations by decreasing winter precipitation, produce substantial reductions in snowpack in the Sierra Nevada Mountains, with cascading impacts on California winter recreation, streamflow, and water storage and supply. Snowpack SWE was estimated by using daily, bias-corrected and spatially downscaled temperature and precipitation to drive the Variable Infiltration Capacity distributed land surface hydrology model. The Variable Infiltration Capacity model, using the resolution and parameterization also implemented in this study, has been shown to reproduce observed streamflows when driven by observed meteorology (10) and has been applied to simulate climate change (8) in this region. April 1 SWE decreases substantially in all simulations before midcentury (see Fig. 15, which is published as supporting information on the PNAS web site). Reductions are most pronounced at elevations below 3,000 m, where 80% of snowpack storage currently occurs (Table 1 and Fig. 2). Interscenario differences emerge before midcentury for HadCM3 and by the end of the century for both models. These changes will delay the onset of and shorten the ski season in California (see *Impact of Decreasing Snowpack on California's Ski Industry* in *Supporting Text*).

Water stored in snowpack is a major natural reservoir for California. Differences in SWE between the B1 and A1fi scenarios represent ≈1.7 km^3 of water storage by midcentury and 2.1 km^3 by the end of the century for HadCM3. For PCM, overall SWE losses are smaller, but the difference between the A1fi and B1 scenarios is larger by the end of the century, representing >4 km^3 of storage. Reductions for all simulations except PCM under the lower B1 emission scenario are greater than previous projections of diminishing snowpack for the end of the century (8, 21). By 2020–2049 the SWE loss is comparable to that previously projected for 2060 (22).

Warmer temperatures and more precipitation falling as rain instead of snow also causes snowmelt runoff to shift earlier under all simulations (Table 1), which is consistent with earlier studies (23). The magnitude of the shift is greater in the higher-elevation Southern basins and under the higher A1fi scenario. Stream inflows to major reservoirs decline because of diminished snowpack and increased evaporation before midcentury, except where winter precipitation increases (Table 1). The greater reductions in inflows seen under A1fi are driven by both higher temperatures and lower average precipitation as compared with B1.

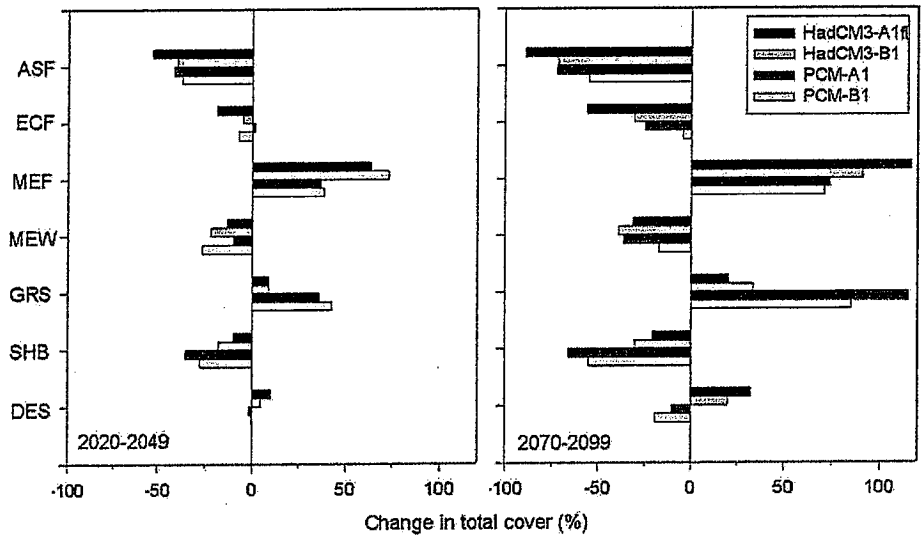

Fig. 3. Statewide change in cover of major vegetation types for 2020–2049 and 2070–2099, relative to simulated distributions for the 1961–1990 reference period. ASF, alpine/subalpine forest; ECF, evergreen conifer forest; MEF, mixed evergreen forest; MEW, mixed evergreen woodland; GRS, grassland; SHB, shrubland; DES, desert. Increasing temperatures drive the reduction in alpine/subalpine forest cover and cause mixed conifer forest to displace evergreen conifer forest in the Sierra Nevada Mountains and the North Coast. Mixed conifer forest in the South Coast expands because of increased humidity and reduced fire frequency. Because of drier conditions and increased fire frequency in inland locations, grassland displaces shrubland and woodland, particularly in the PCM simulations, whereas warmer and drier conditions under HadCM3 cause an expansion of desert cover in the southern Central Valley.

Earlier runoff may also increase the risk of winter flooding (7). Currently, state operators maintain ≈12 km^3 of total vacant space in the major reservoirs to provide winter and early spring flood protection,[n] a volume approximately equal to that stored in the natural snowpack reservoir by April 1st. Capturing earlier runoff to compensate for future reductions in snowpack would take up most of the flood protection space, forcing a choice between winter flood prevention and maintaining water storage for the summer and fall dry period use. Flood risk and freshwater supply are also affected by higher sea levels, which are projected to rise 10–40 cm under B1 and 20–65 cm under A1fi by 2100 (Table 1; see also Fig. 16, which is published as supporting information on the PNAS web site).

Declining Sierra Nevada snowpack, earlier runoff, and reduced spring and summer streamflows will likely affect surface water supplies and shift reliance to groundwater resources, already overdrafted in many agricultural areas in California (24). This could impact 85% of California's population who are agricultural and urban users in the Central Valley, San Francisco Bay Area, and the South Coast, about half of whose water is supplied by rivers of the Central Valley. Under A1fi (both models) and B1 (HadCM3), the projected length, frequency, and severity of extreme droughts in the Sacramento River system during 2070–2099 substantially exceeds what has been experienced in the 20th century. The proportion of years projected to be dry or critical increases from 32% in the historical period to 50–64% by the end of the century under all but the wetter PCM B1 scenario (see Table 2, which is published as supporting information on the PNAS web site). Changes in water availability and timing could disrupt the existing pattern of seniority in month-dependent water rights by reducing the value of rights to mid- and late-season natural streamflow and boosting the value of rights to stored water. The overall magnitude of impacts on water users depends on complex interactions between temperature-driven snowpack decreases and runoff timing, precipitation, future population increases, and human decisions regarding water storage and allocation (see *Impacts on Water Supply* in *Supporting Text*).

Impacts on Agriculture and Vegetation Distribution

In addition to reductions in water supply, climate change could impact California agriculture by increasing demand for irrigation to meet higher evaporative demand, increasing the incidence of pests (25), and through direct temperature effects on production quality and quantity. Dairy products (milk and cream, valued at $3.8 billion annually) and grapes ($3.2 billion annually) are the two highest-value agricultural commodities of California's $30 billion agriculture sector (26). Threshold temperature impacts on dairy production and wine grape quality were calculated by using downscaled temperature projections for key counties, relative to average observed monthly temperatures.[o]

For dairy production, losses were estimated for temperatures above a 32°C threshold (27), as well as for additional losses between 25°C (28) and 32°C. For the top 10 dairy counties in the state (which account for 90% of California's milk production), rising temperatures were found to reduce production by as much as 7–10% (B1) and 11–22% (A1fi) by the end of the century (see Table 3, which is published as supporting information on the PNAS web site). Potential adaptations may become less practical with increasing temperature and humidity (29).

For wine grapes, excessively high temperatures during ripening can adversely affect quality, a major determinant of market value. Assuming ripening occurs at between 1,150 and 1,300 biologically active growing degree days (30), ripening month was determined by summing modeled growing degree days above 10°C from April to October, for both baseline and projected scenarios. Monthly average temperature at the time of ripening was used to estimate potential temperature impacts on quality. For all simulations, average ripening occurs 1–2 months earlier and at higher temperatures, leading to degraded quality and marginal/impaired conditions for all but the cool coastal region

[n]See the U.S. Army Corps of Engineers Flood Control Requirements for California Reservoirs, Sacramento District Water Control Data System, Sacramento, CA (www.spk-wc.usace.army.mil).

[o]See Western U.S. Climate Historical Summaries (Western Regional Climate Center) at www.wrcc.dri.edu/climsum.html.

under all scenarios by the end of the century (see Table 3, which is published as supporting information on the PNAS web site). As with other perennial crops, adaptation options to shift varieties or locations of production would require significant time and capital investment.

The distribution of California's diverse vegetation types also changes substantially over the century relative to historical simulations (Fig. 3; see also Fig. 17, which is published as supporting information on the PNAS web site). Projections of changes in vegetation distribution are those given by MC1, a dynamic general vegetation model that simulates climate-driven changes in life-form mixtures and vegetation types; ecosystem fluxes of carbon, nitrogen, and water; and fire disturbance over time (31). Vegetation shifts driven primarily by temperature, such as reductions in the extent of alpine/subalpine forest and the displacement of evergreen conifer forest by mixed evergreen forest, are consistent across models and more pronounced under A1fi by the end of the century. Changes driven by precipitation and changes in fire frequency are model-dependent and do not exhibit consistent interscenario differences. Most changes are apparent before mid-century, with the exception of changes in desert cover. The shift from evergreen conifer to mixed evergreen forest and expansion of grassland are consistent with previous impact analyses (13), whereas the extreme reduction in alpine/subalpine forest and expansion of desert had not been reported in previous impacts assessments (12, 13).

Conclusions

Consistent and large increases in temperature and extreme heat drive significant impacts on temperature-sensitive sectors in California under both lower and higher emissions scenarios, with the most severe impacts occurring under the higher A1fi scenario. Adaptation options are limited for impacts not easily controlled by human intervention, such as the overall decline in snowpack and loss of alpine and subalpine forests. Although interscenario differences in climate impacts and costs of adaptation emerge mainly in the second half of the century, they are largely entrained by emissions from preceding decades (32). SRES scenarios do not explicitly assume climate-specific policy intervention, and thus this study does not directly address the contrast in impacts due to climate change mitigation policies. However, these findings support the conclusion that climate change and many of its impacts scale with the quantity and timing of greenhouse gas emissions (33). As such, they represent a solid starting point for assessing the outcome of changes in greenhouse gas emission trajectories driven by climate-specific policies (32, 34), and the extent to which lower emissions can reduce the likelihood and thus risks of "dangerous anthropogenic interference with the climate system" (35).

We thank Michael Dettinger and Mary Meyer Tyree for providing assistance with data and analysis, and Frank Davis for providing review of earlier drafts of this manuscript. PCM model results were provided by PCM personnel at the National Center for Atmospheric Research, and HadCM3 model results were provided by Dr. David Viner from the U.K. Met Office's Climate Impacts LINK Project. This work was supported in part by grants from the David and Lucile Packard Foundation, the William and Flora Hewlett Foundation, the Energy Foundation, the California Energy Commission, the National Oceanic and Atmospheric Administration Office of Global Programs, and the Department of Energy.

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attachment #15

COMMENTS ON DWR'S TECHNICAL MEMORANDUM

"Progress on Incorporating Climate Change into Management of California's Water Resources", July 2006

By Arve R. Sjovold
September 2, 2006

In DWR'S year 2002 report on the "The State Water Project Delivery Reliability Report" it was explicitly acknowledged that climate change would affect the timing and amounts of snowfall and possibly precipitation and that sea level rise was likely. At that time the timing of these impacts was speculative. That report promised that more definitive studies of the impact on climate change would be provided, possibly as soon as the update of the California Water Plan Update 2003. Thus, it was with some anticipation that I looked forward to a comprehensive study of the affects of climate change on the SWP. The subject report fails to provide that comprehensive study. Although DWR did engage in some rather elaborate computerized calculations, the subject of those calculations studiously avoided the impacts, now more widely recognized, but clearly acknowledged in the 2002 Reliability Report. Any keenly interested observer of the debate on climate change would have expected a cogent and objective analysis of the effects of sea level rise and changed Sierra run-off patterns as first order effects.

The report devotes considerable of its quantitative analyses to the calculations of the effects of a very modest sea level rise of 15 inches on the ability of the Delta to deliver water to the pumps without severe violations of salinity thresholds. It does so based on assumptions that upstream reservoir operations are not changed and that sea level rise does not change the hydraulic network in the Delta. Another assumption for this analysis is that the salinity gradient in the western Delta does not change with this sea level rise. No supporting evidence or analysis is given as to why these assumptions are reasonable. In other words, a primary assumption is that the current system of Delta levies remains in tact with a 15 inch sea level rise. I won't argue that that level of sea level rise may indeed leave the levies operationally in tact, but it misses the first order question of what level of sea level rise will compromise the system of levies. There are good maps (produced by DWR, if I am not mistaken) of what the Delta may look like with 1, 2, 4, and 10-foot sea level rises. From these maps it is clear that somewhere between 2 and 4 feet of rise there is little assurance that the Delta can perform as a delivery network of fresh water to the South Delta pumps. Since the subject report acknowledges that 2.9 feet of sea level rise is likely under one of the scenarios studied by the International Panel on Climate Change (IPCC) by the end of the century, clearly the most important question to be addressed by DWR is to calculate at what level the Delta's levies cannot be relied upon. **The subject report does not do this and does not offer a qualitative discussion.**

The other major assumption underlying their quantitative calculations is that reservoir operations (that is, Oroville and Shasta) are not changed by climate change impacts. That this is an untenable assumption is apparent from the report's side study that shows under 3 different scenarios that peak discharge from the Feather River may be

substantially altered. In fact, the most severe scenario carefully quantifies that peak discharge for a "15 year event" may be 2 ½ times the current estimate of a 15-year peak discharge. Clearly, any inquiring mind would wonder how reservoir operations might be affected by such a finding. Curiously, the report does not inquire further. But that may be the most intriguing finding of the report. If as a matter of hydrology peak discharges at any return level are 2 ½ times higher, such a finding would call into question the ability of the dams to function as designed. First, 2 1/2 times peak discharge would probably tax the design limits of dam spillways. Second, flood pools in reservoirs would have to be enlarged compromising water conservation objectives. Third, passage of discharges 2 1/2 times as large would undoubtedly cause havoc below the dams. None of this is addressed in the report even though that is where it should logically lead.

In conclusion, the report shows no scientific curiosity concerning the very likely first order impacts of climate change. The detailed quantitative analyses that are performed are totally irrelevant to what are the major questions that are posed by climate change. The report should candidly state that the most reasonable forecasts of what climate change might produce would seriously compromise the project, to the extent that the SWP may be obsolete in its current configuration within the current century. This is certainly a different tone than that conveyed by this report.

Specific Criticisms

1) The report still relies on CALSIM II as a reliable model to study the impacts of climate change. First, as we have so many times stated in the past CALSIM II is a fatally flawed model. It has not been calibrated and is not a true simulation model, as it is commonly referred to. Second, the indices that are use to drive the model in certain of its calculations are without scientific or practical merit. They provide the so-called simulation with perfect information of stream flows in advance of simulated operational decisions and the indices are highly distorted representations of the true stochastic nature of the operational problem, simulating operations in the face of uncertain future stream flows. It is particularly noteworthy that the CALSIM II run labeled "Base" in the report does not resemble the CALSIM II 2021-runs performed for the Reliability Report for ostensibly the very same assumptions. In fact, the variance between these two case studies, the "2021" study in the reliability report and the "Base" in the climate change study, is roughly the same as the differences reported between the "Base" case in the climate change study and the alternative scenarios. (See Table 1 below.) In stark terms, we are using a measuring instrument that is too imprecise to reliably distinguish differences among the scenarios. Scientifically, the model is inappropriate just on that finding and DWR staff should be required to establish why there are such differences between these two reports.

2) Throughout a significant portion of the report detailing previous hydrologic history of the Central Valley, there are many regression analyses results that are portrayed to establish certain trends that may have some significance. The report does not state why they may be relevant. I find it difficult to see any

such relevance except if it is to acknowledge that some climate change may have already occurred. Even then, I fail to see the relevance absent any analysis that shows why it should be. Beyond that observation of relevance, there is the more important issue of deciding when a calculated trend is significant. It appears from the data presented in the report that many of the trends are statistically insignificant at normally accepted thresholds. Why such trends are reported as maybe "real" is puzzling.

3) The preoccupation with the affects of climate change on stream flow temperatures is probably misplaced. Given that current project operations are decimating species in the Delta, the concern seems an attempt to show that the species are doomed anyway and we shouldn't worry about what the projects are doing now. That is a very shortsighted view and seems to be extremely self-serving with respect to current operations. My view would show more emphasis on characterizing future overall stream flow amounts and timing rather than on speculations on stream-flow temperatures as if the basic stream flows are relatively unperturbed.

4) The report does provide a fairly decent summary of the extant scientific theories supporting global warming and the effects on climate. The report depends most strongly on the work reported by the IPCC and the scenarios they cast. However, other more recent work out of the Goddard Space Science Institute (GSSI) strongly suggests that ice sheet breakup of the Greenland and/or Antarctic ice sheets may accelerate sea level rise significantly, an event that is not a major factor in the IPCC scenarios. If the GSSI theory is more correct the integrity of the Delta in the nearer future may be in doubt. Neither the IPCC nor the GSSI can offer precise timelines as to when significant sea level rise may occur. Nonetheless, it is vitally important that DWR include a candid appraisal of the likelihood of sea level impacts on the Delta beyond the mere 15-inch rise assumed in their studies. Calculations can easily show that the generally accepted existing level of climate forcing, .85 watts/m^2, is sufficient to melt sufficient ice to raise sea level by 0.4 feet per year. What is not certain is how future climate forcing will divide between melting ice and warming the biosphere. It is very clear right now that the rate of sea level rise cannot be estimated precisely but the potential for rapid sea level rise is the most important feature of global warming. The report should candidly state so.

5) The report summarizes the past history that has been developed for global warming over the past 650,000 years which shows that within our recorded history the Earth is near a peak warm temperature for this interval. If the report had included the corresponding data on the coincidence of greenhouse gas concentrations and sea levels with temperature (See attachment) it would be quite clear that greenhouse gases are the most significant driver of temperature change and consequent sea level rise. The DWR report does include a table of the existing concentrations of CO_2 and methane,

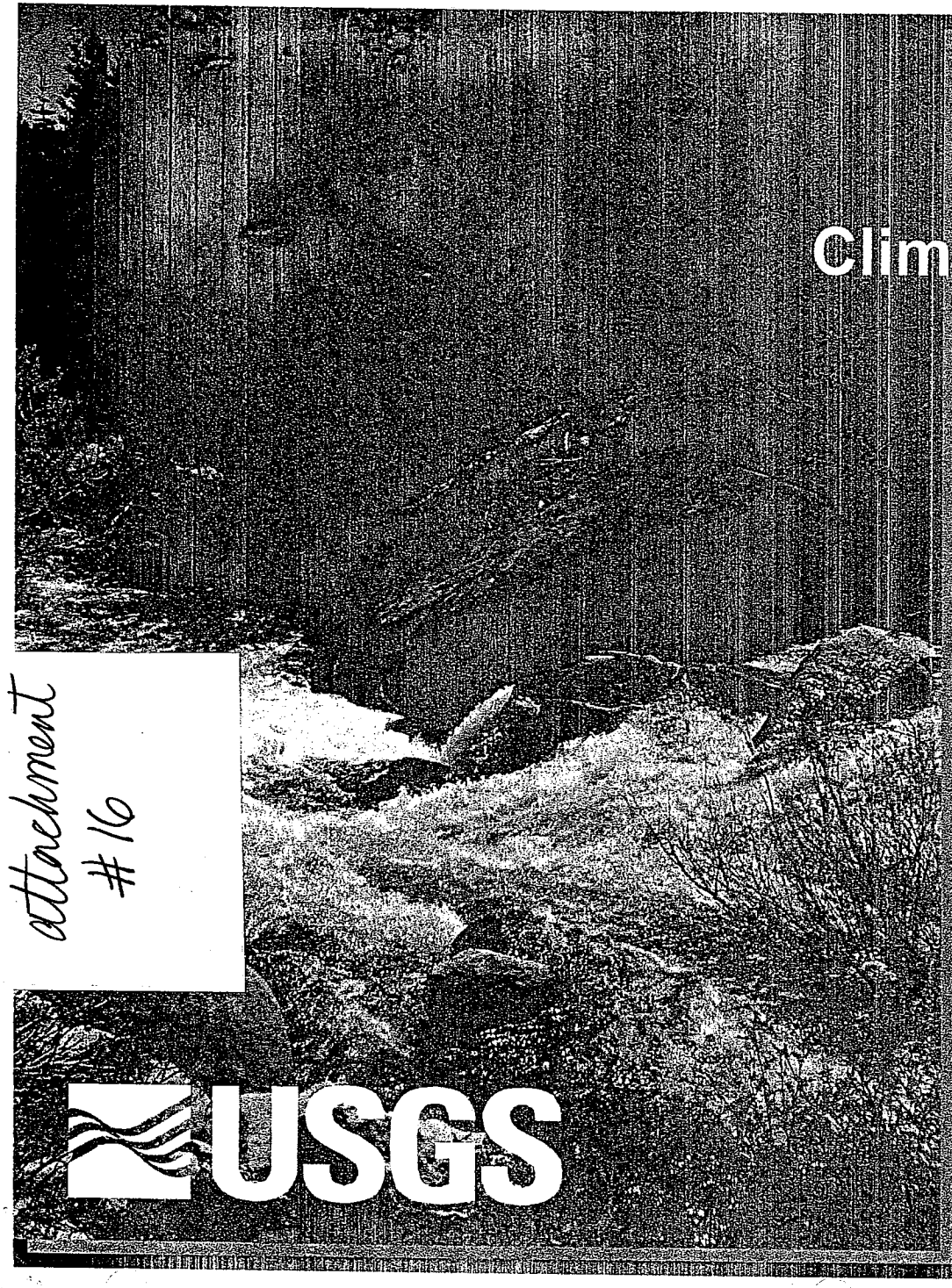
corroborated in the attachment, which are higher than ever measured by the ice cores within the past 650,000 years. This remarkable finding should require the widest possible range of possible changes rather than the restricted ranges chosen by the report. In short, the authors of the report did not delve deeply enough into the current research being performed on climate change and the report cannot claim to have met its objective of "incorporating climate change into the SWP."

6) The analysis to incorporate climate change into CALSIM II involves an intricate attempt to translate IPCC climate change scenarios into specific quantitative changes in major Northern California river run-off as the basis of the computer calculations that form the major effort of the report. It is noted in the analysis that the climate change scenarios are based on global models that incorporate only six grid points to characterize expected rainfall for all of California. The analysis then proceeds to use the information developed for these six grid points to generate estimated changes for 10 of the major rivers. Another model, the Variable Infiltration Capacity (VIC) model, is used to calculate these estimated changes of rainfall into run-off. An important assumption in this exercise is the use of the VIC model to develop perturbation ratios due to climate change that can then be used to modify the characteristic run-off measurements for these rivers. The clear flaw in this methodology is the measured run-off used to characterize the rivers. The analysts chose the year 1976, a readily acknowledged drought year to characterize the average or "normal" run-off. Since 1976 was well below average for any river system in California, this choice necessarily biases the estimated changes low. 1976 run-off was probably less than half the average. Therefore, on translating changed rainfall into estimated run-off for the major rivers feeding the CVP and SWP, the use of 1976 as a basis to scale from as described in the report necessarily underestimates the run-offs under climate change by a significant amount. Accordingly, the entire exercise with the Delta model, DSM, is not even a reasonable estimate. Since this computer exercise seems to comprise the most substantive portion of the report, it calls into question any and all of its findings. DWR should be required to justify the choice of 1976 (although on its face it seems that this can't be done). A standard analysis of this type would have done so as a matter of course.

Table 1
Comparison of "Base" and 2021 CALSIM II Runs

(Million acre-feet per year)

Water Year	Climate Change Report SWP Exports	2002 Reliability Report SWP Exports Fixed Demand	Variance
76	2.97	2.78	.19
77	1.00	0.83	.17
78	3.61	3.91	.30
79	3.70	3.49	.21
80	4.10	3.46	.64
81	3.33	3.40	.07
82	4.71	4.13	.58
83	3.68	4.13	.45
84	3.42	4.10	.68
85	3.52	3.32	.20
86	4.20	3.01	1.19
87	2.57	2.84	.27
88	1.54	0.99	.55
89	2.72	2.90	.18
90	1.60	1.15	.45
91	1.10	1.00	.10
Average Variance			**0.39**



attachment #16

Climate Change and Water Supplies in the West

Michael Dettinger, USGS

USGS

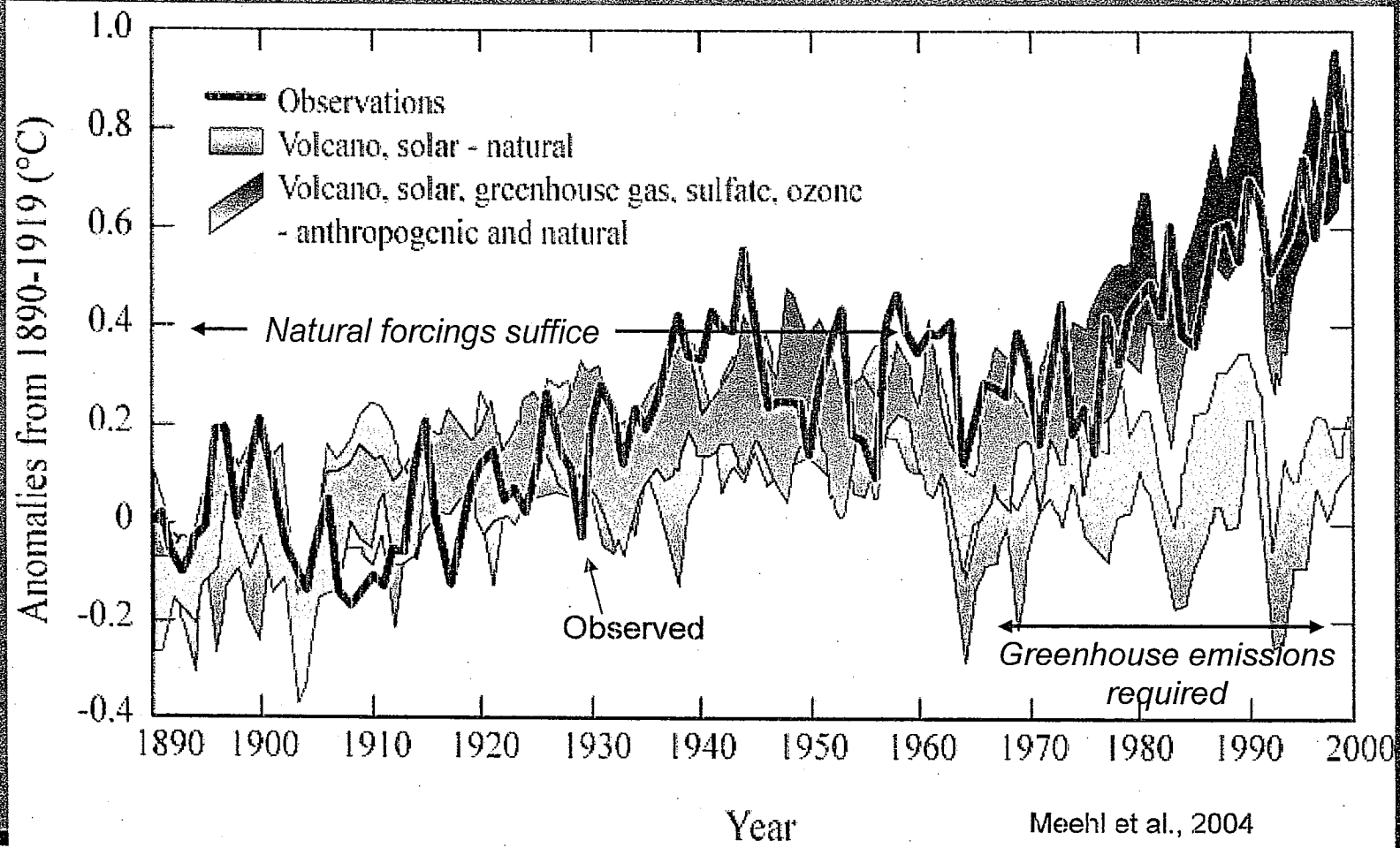
Scripps Institution of Oceanography

CEC's California Climate Change Center

NOAA OGP's California Applications Program

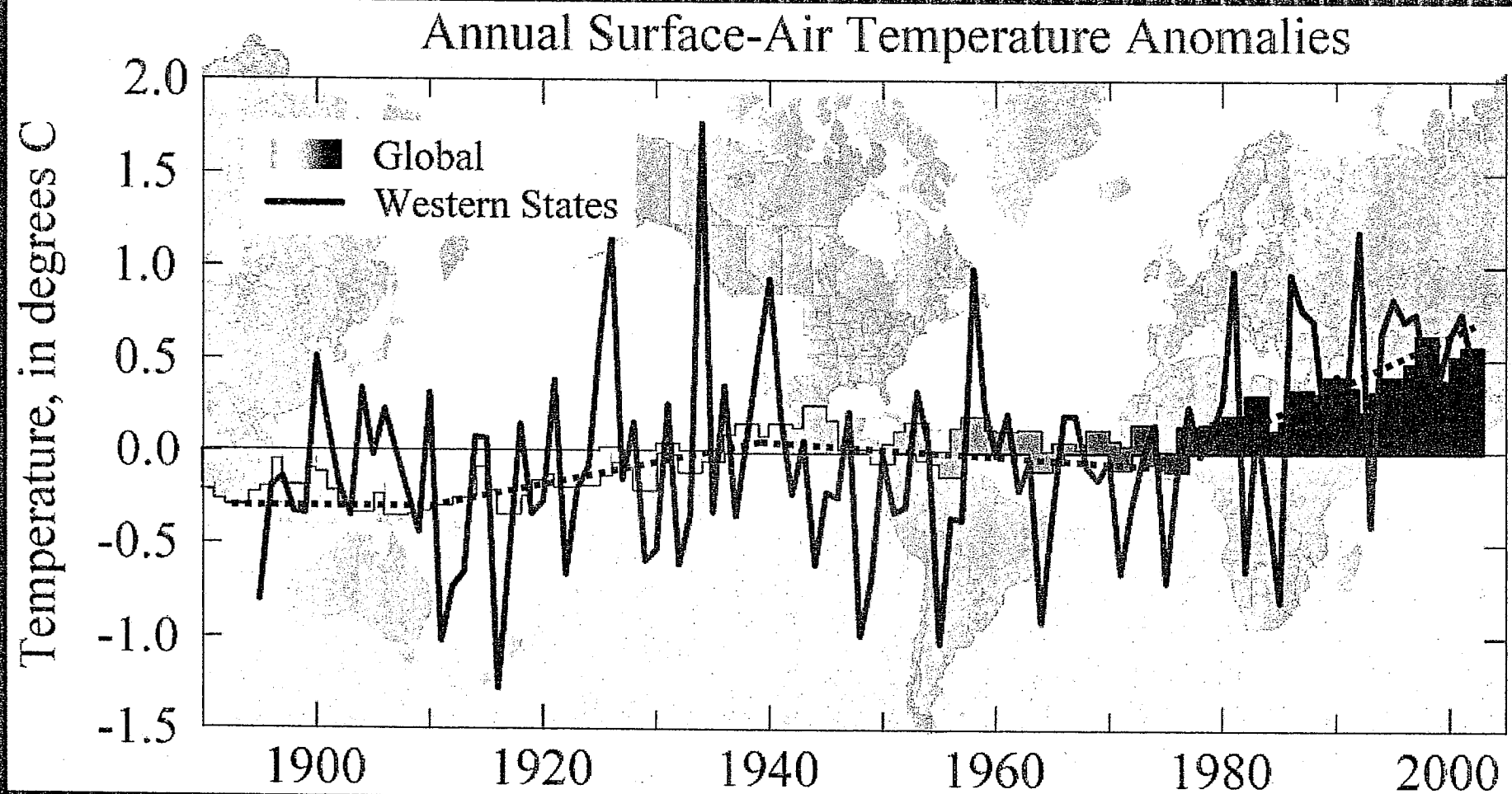
During the past 30 years--and in the near-term future--natural climate variability has been *augmented* by warming trends associated with increases in the global greenhouse effect.

Climate-model simulations of global-average temperature



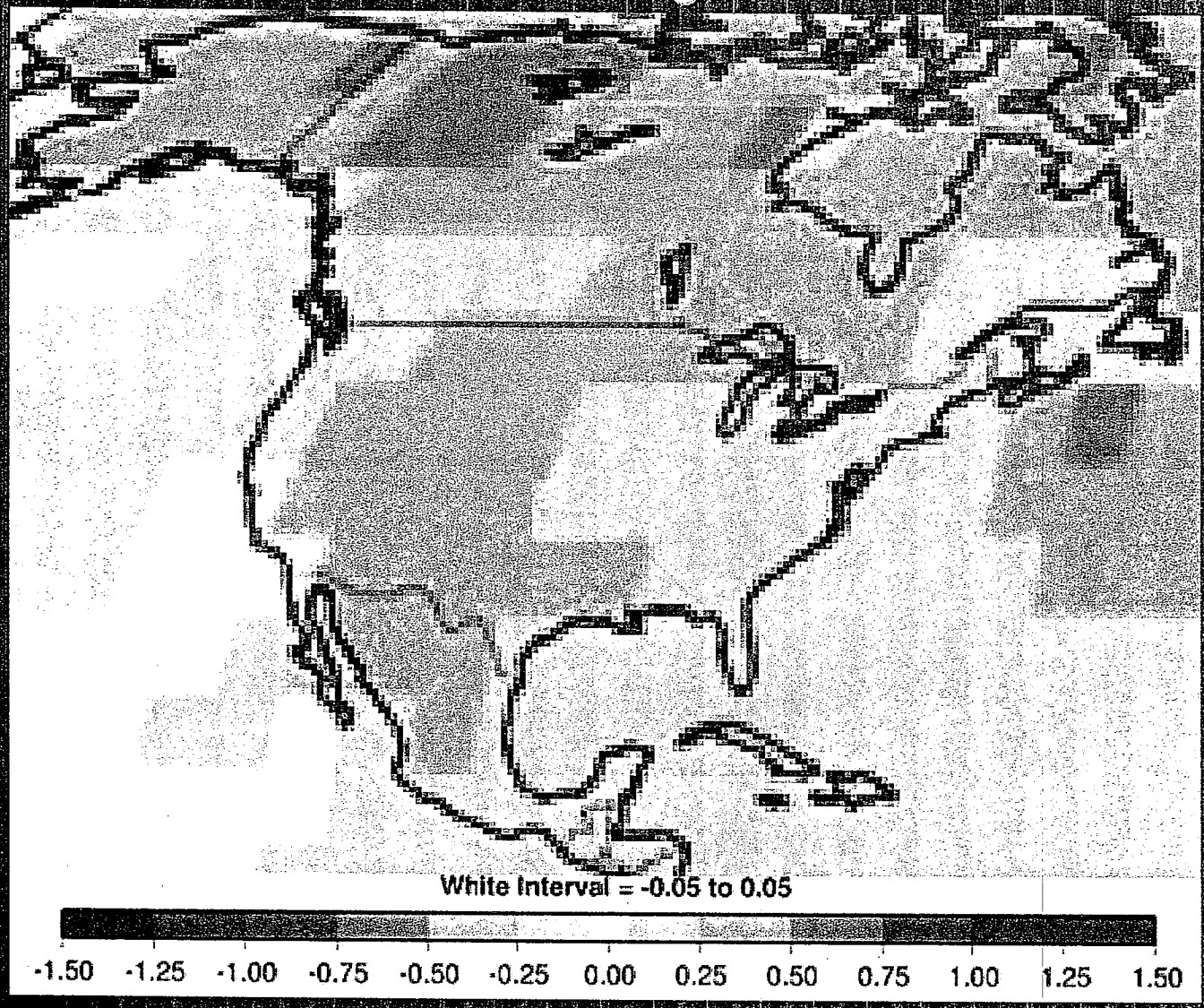
Meehl et al., 2004

...and observed temperatures in the Western States have followed pretty faithfully.



USGS

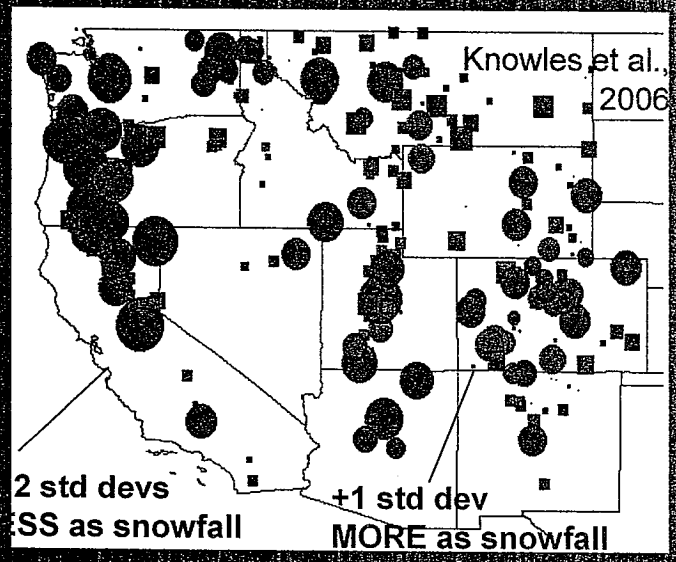
Observed Warming, 1979-2005

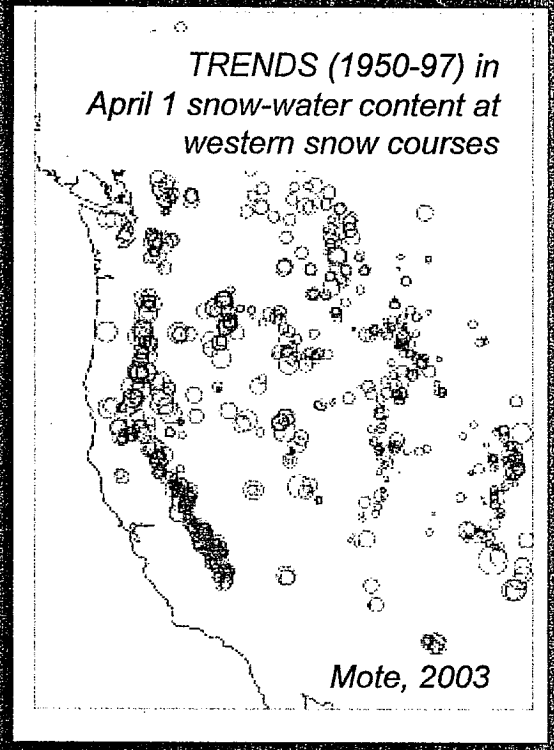


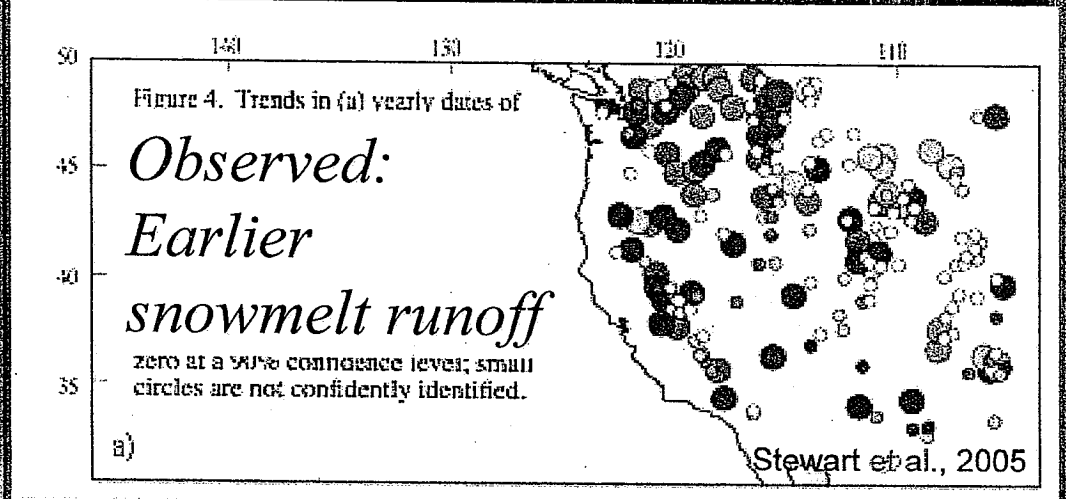
Annual-mean warming, degree C/decade

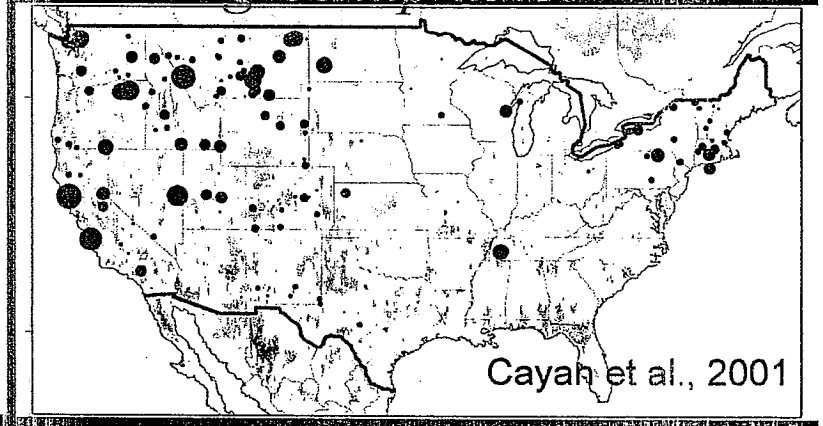
IPCC 4th Assessmt, WG1 Ch. 4, 2007

Warming already has driven observable hydroclimatic change

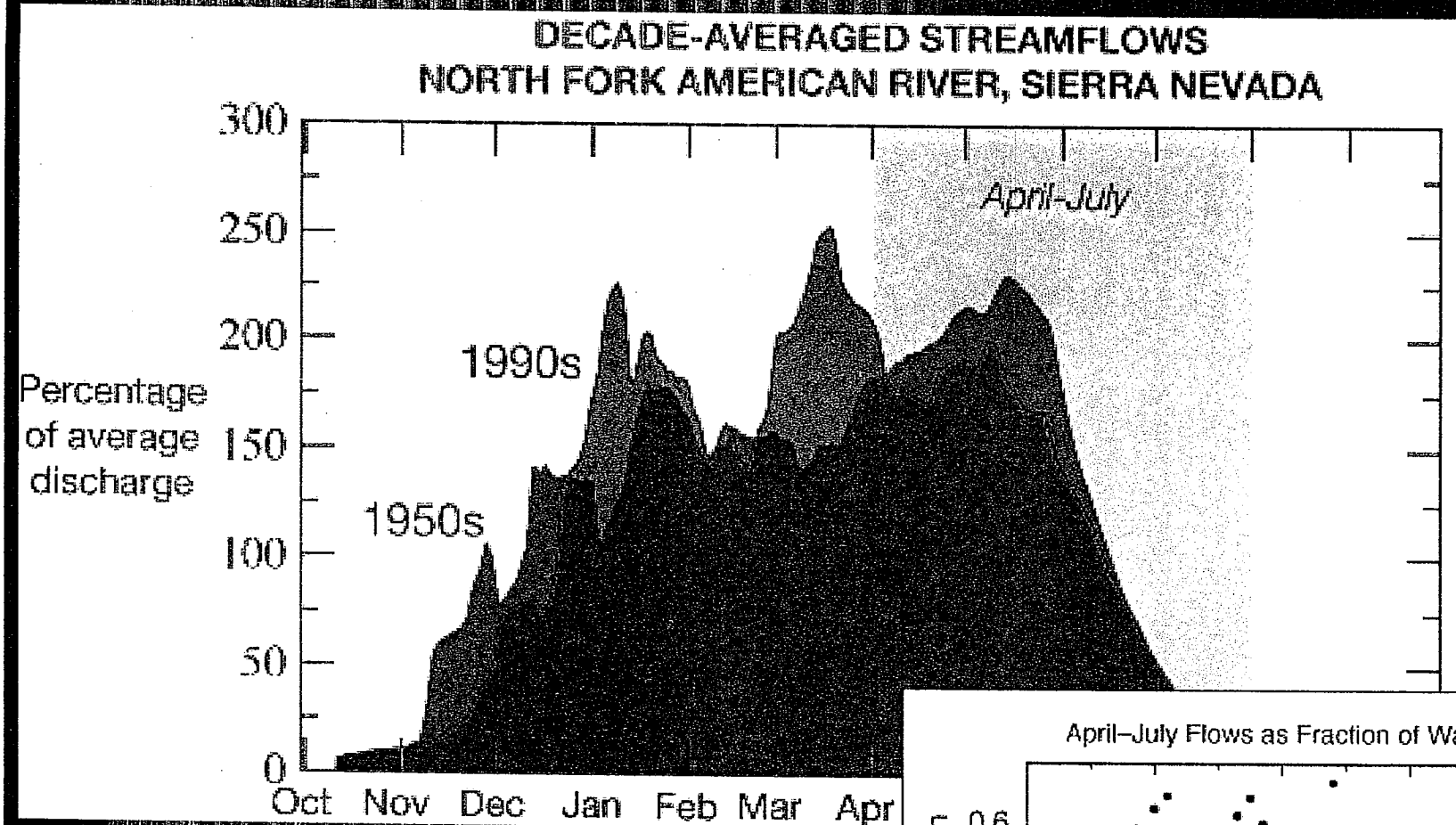


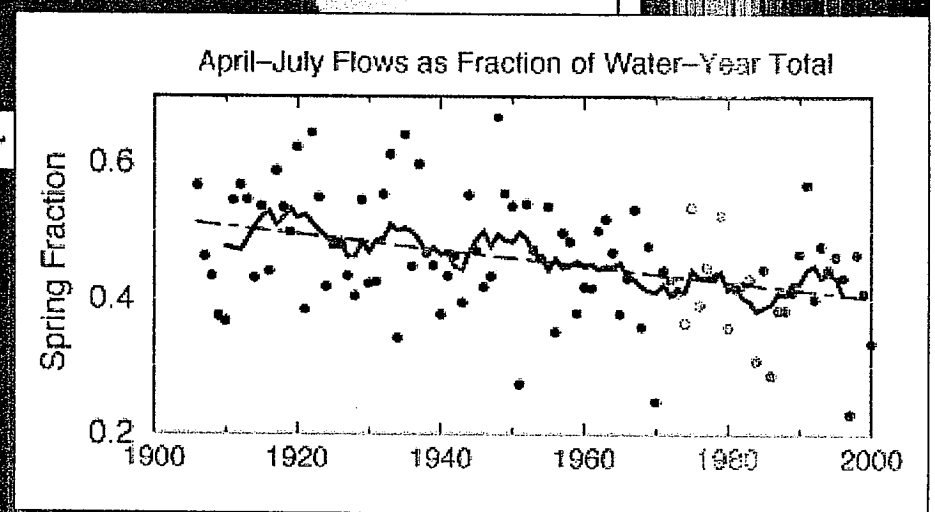






As a result of these trends, the warm-season fraction of annual streamflow has declined.

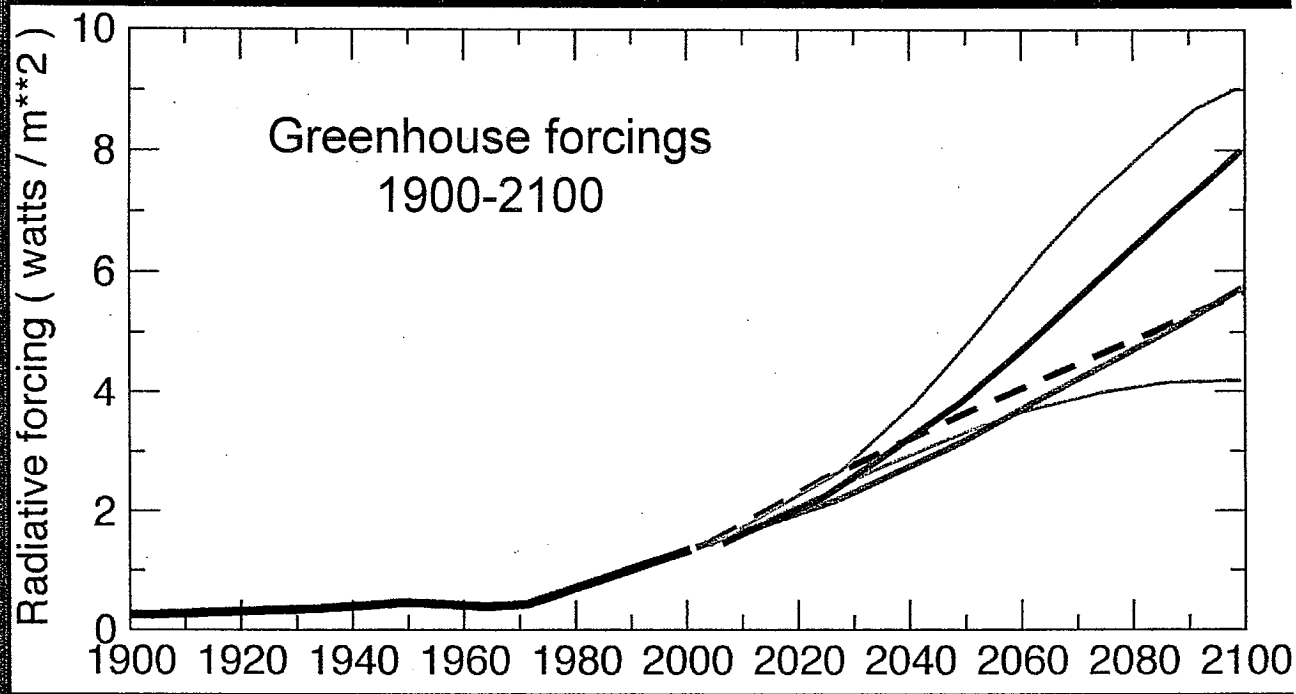


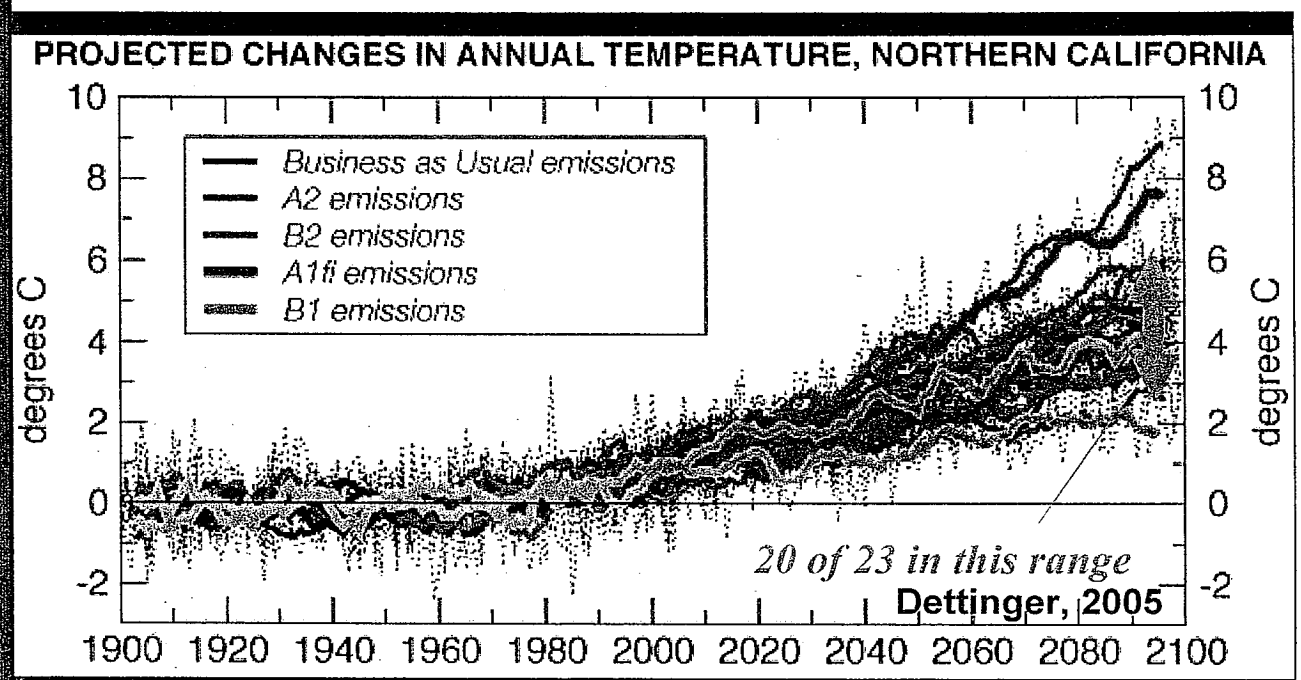


Roos, 1989, 1991; Dettinger and Cayan, 1995; Stewart et al 2005

USGS

Under projected greenhouse forcings, all climate models yield warmer futures for California and the West.



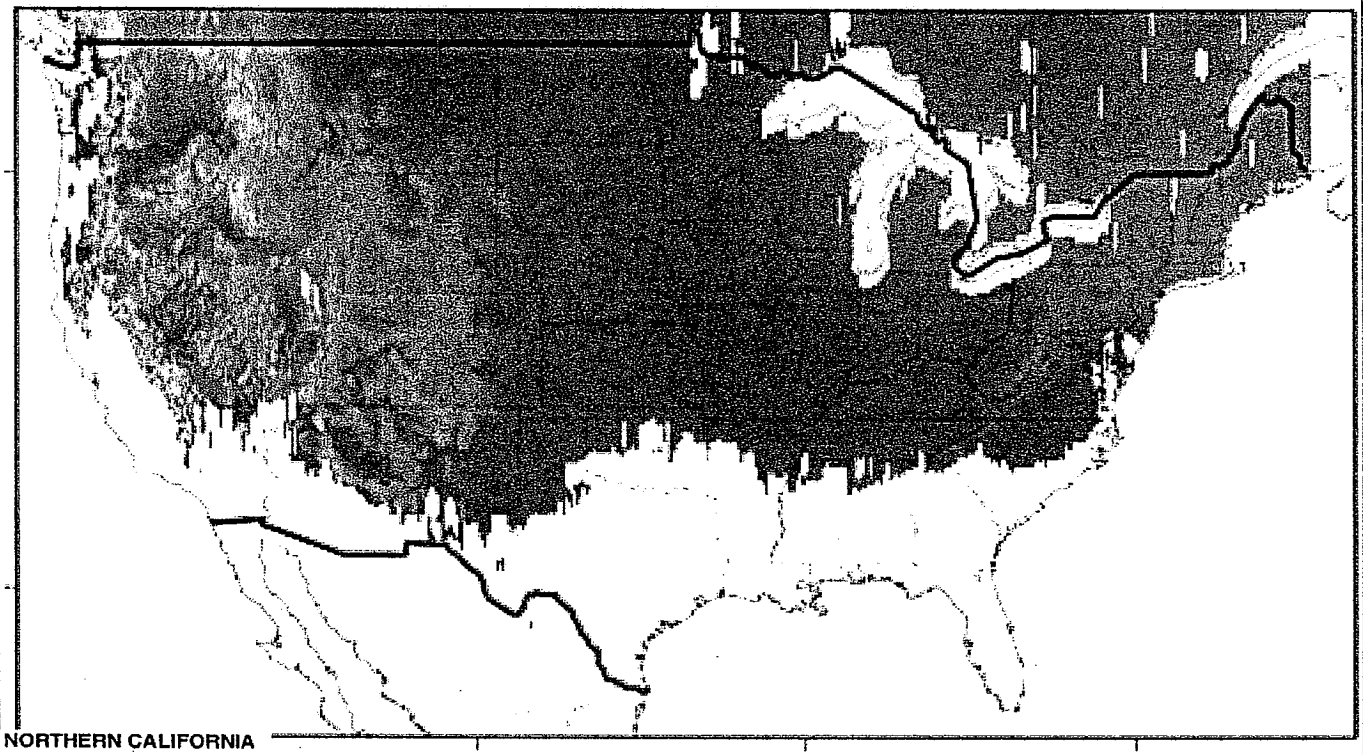


USGS

To put these levels of of warming into perspective:

What fraction of precipitation historically fell on days with average temperatures just below freezing?

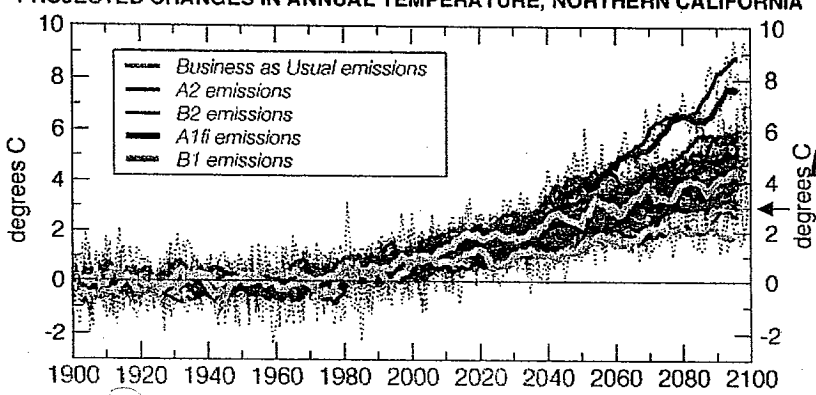
FRACTION OF ANNUAL PRECIPITATION FALLING
IN THE DAILY TEMPERATURE RANGE: -3C < Tavg < 0C
[from 1950-1999 VIC 1/8-degree INPUT DATA]



0.00 0.15 0.25 0.35

Less change FRACTION **More change**

PROJECTED CHANGES IN ANNUAL TEMPERATURE, NORTHERN CALIFORNIA



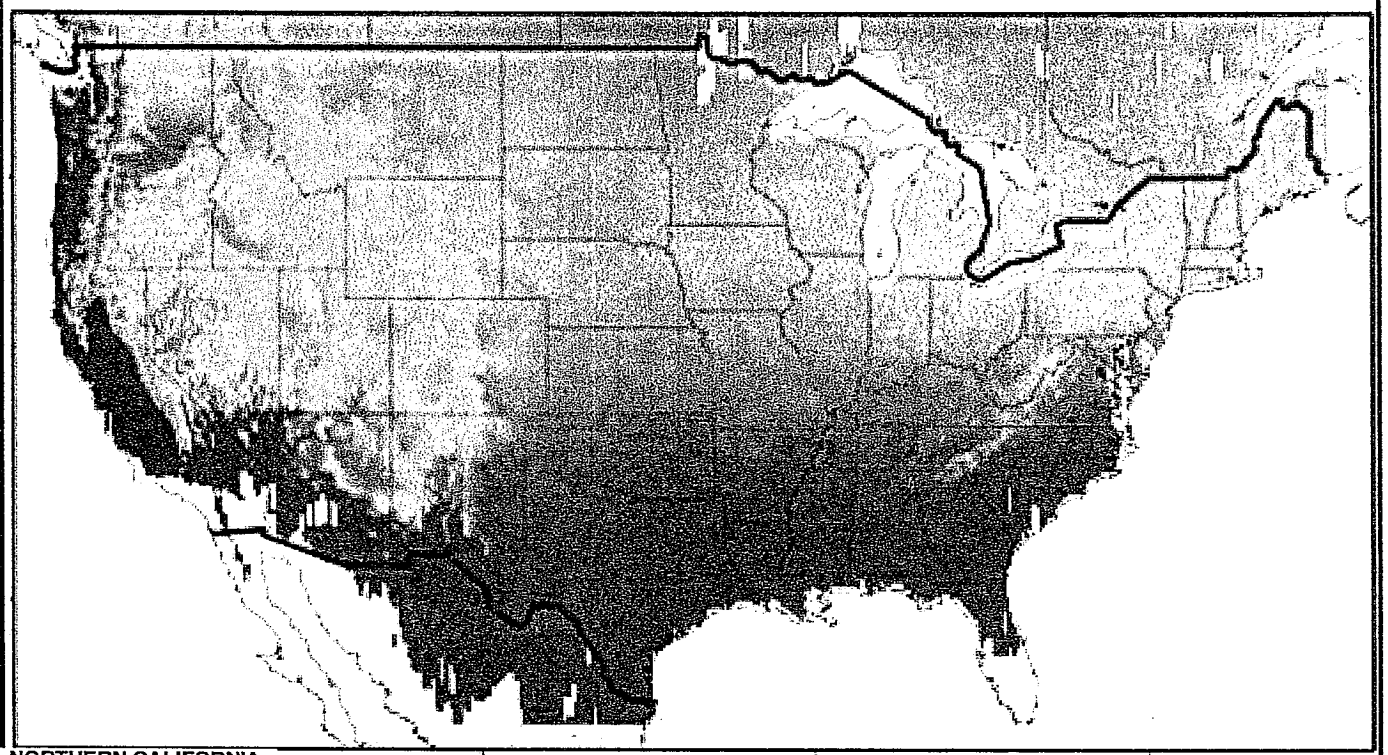
"Rain vs Snow"

Computed from UW's VIC model daily INPUTS (Bates et al. 2006)

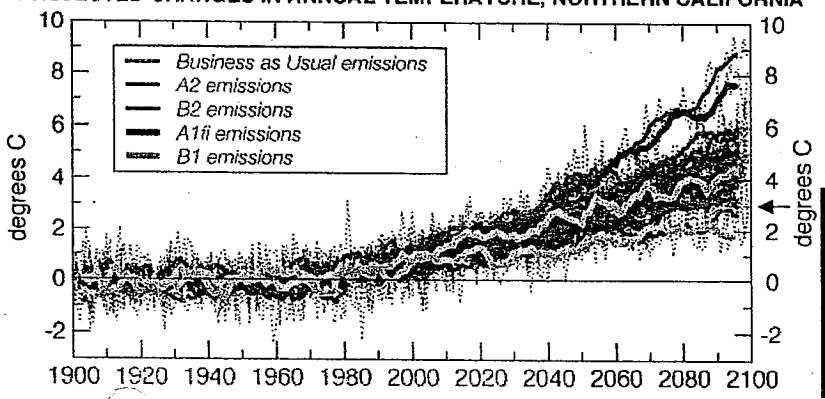
To put these levels of of warming into perspective:

How many days/year historically were just below freezing?

NUMBER OF DAYS/YEAR WITH MEAN TEMPERATURES
IN THE RANGE: -3C < Tavg < 0C
[from 1950-1999 VIC 1/8-degree INPUT DATA]



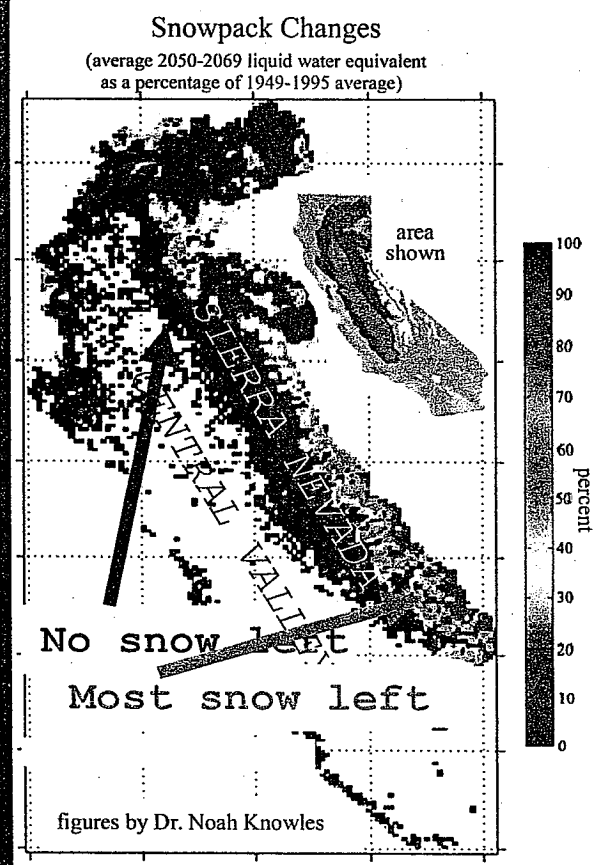
PROJECTED CHANGES IN ANNUAL TEMPERATURE, NORTHERN CALIFORNIA

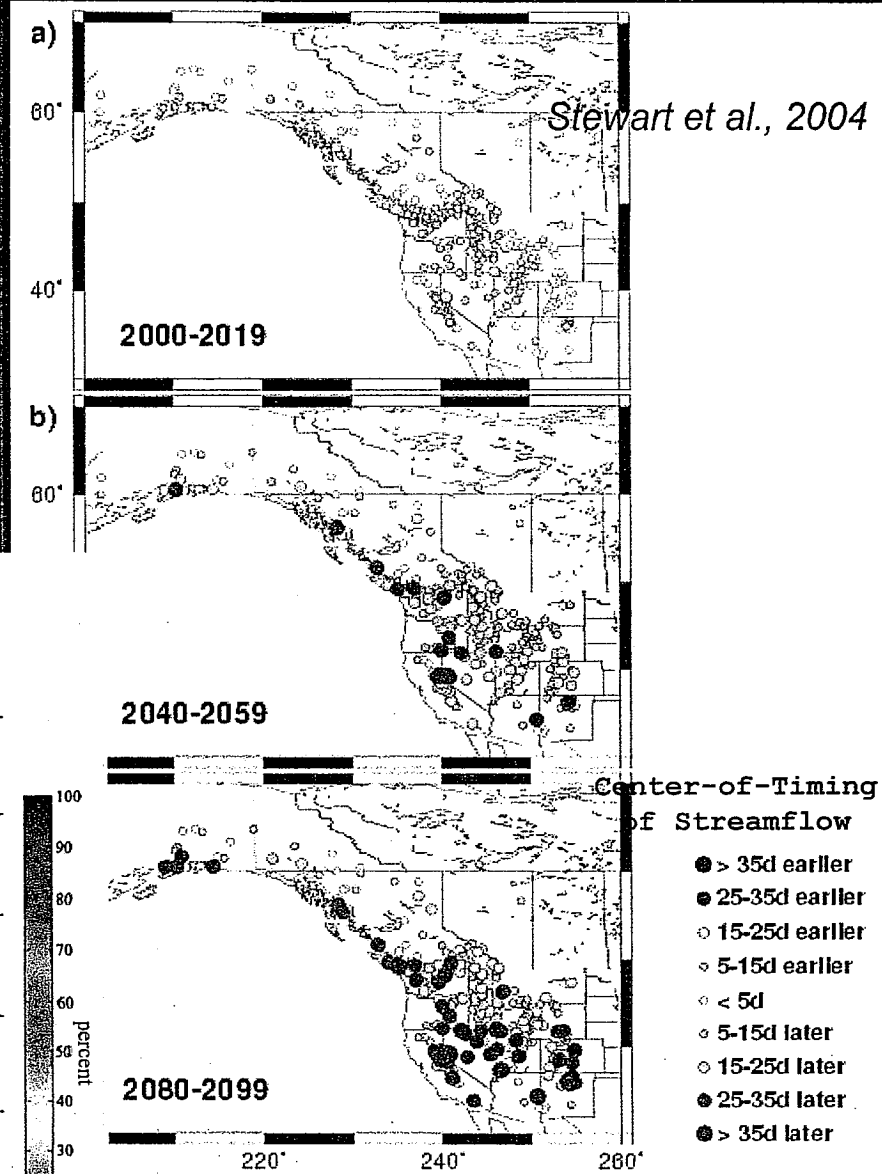


"Duration of Snowpack"

Computed from UW's VIC model daily INPUTS (Bates et al. 2006)

Under even the coolest of these scenarios, historical streamflow-timing trends in snowfed streams are projected to continue in 21st Century.



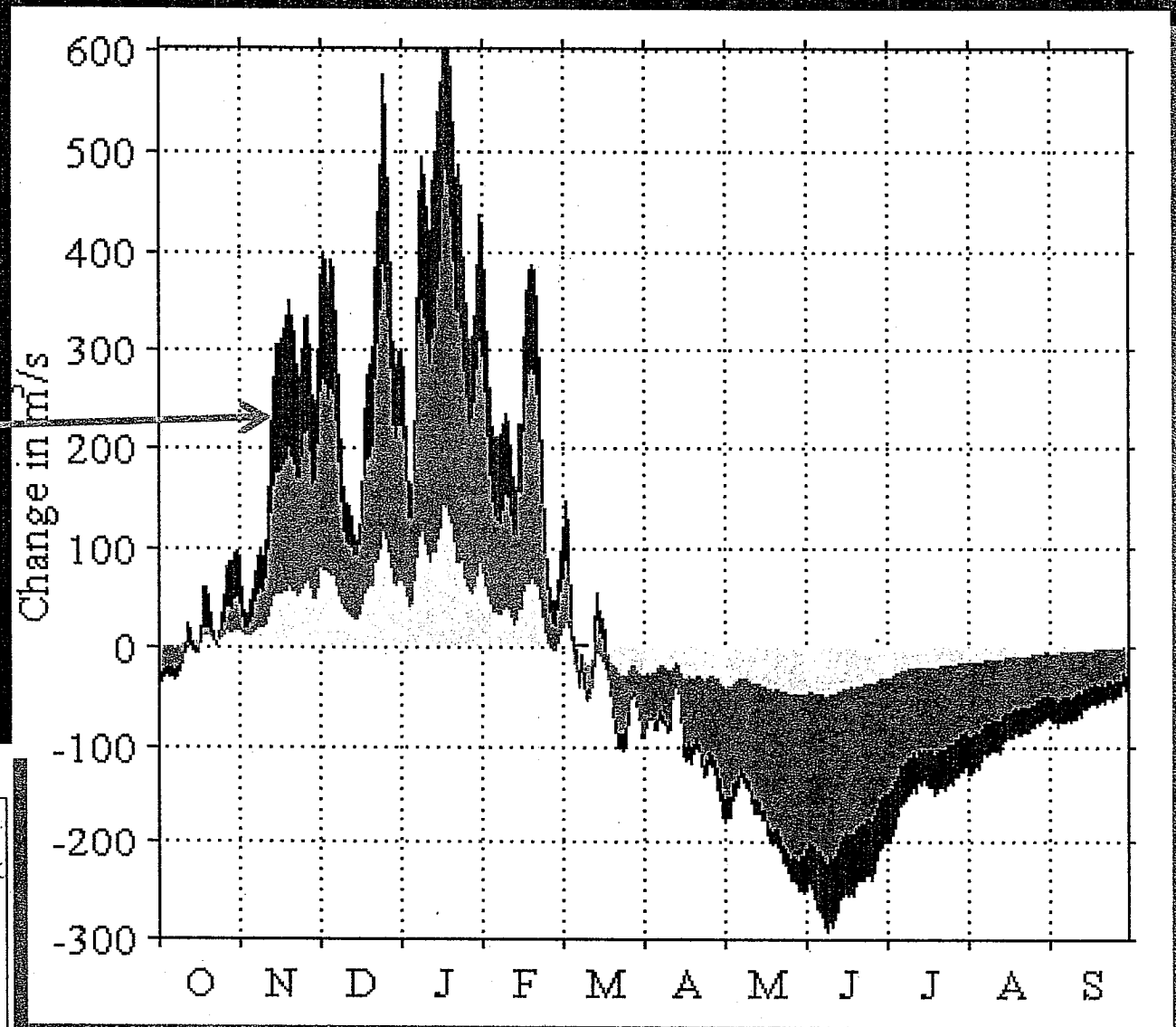


Stewart et al., 2004

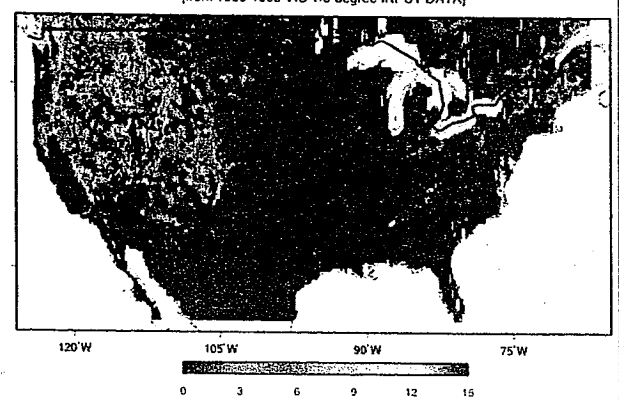
USGS

Changes in Sierra Nevada Outflow, 2060 – 2000

Besides changing flow seasonality, these changes may bring more severe winter floods in at least some settings…

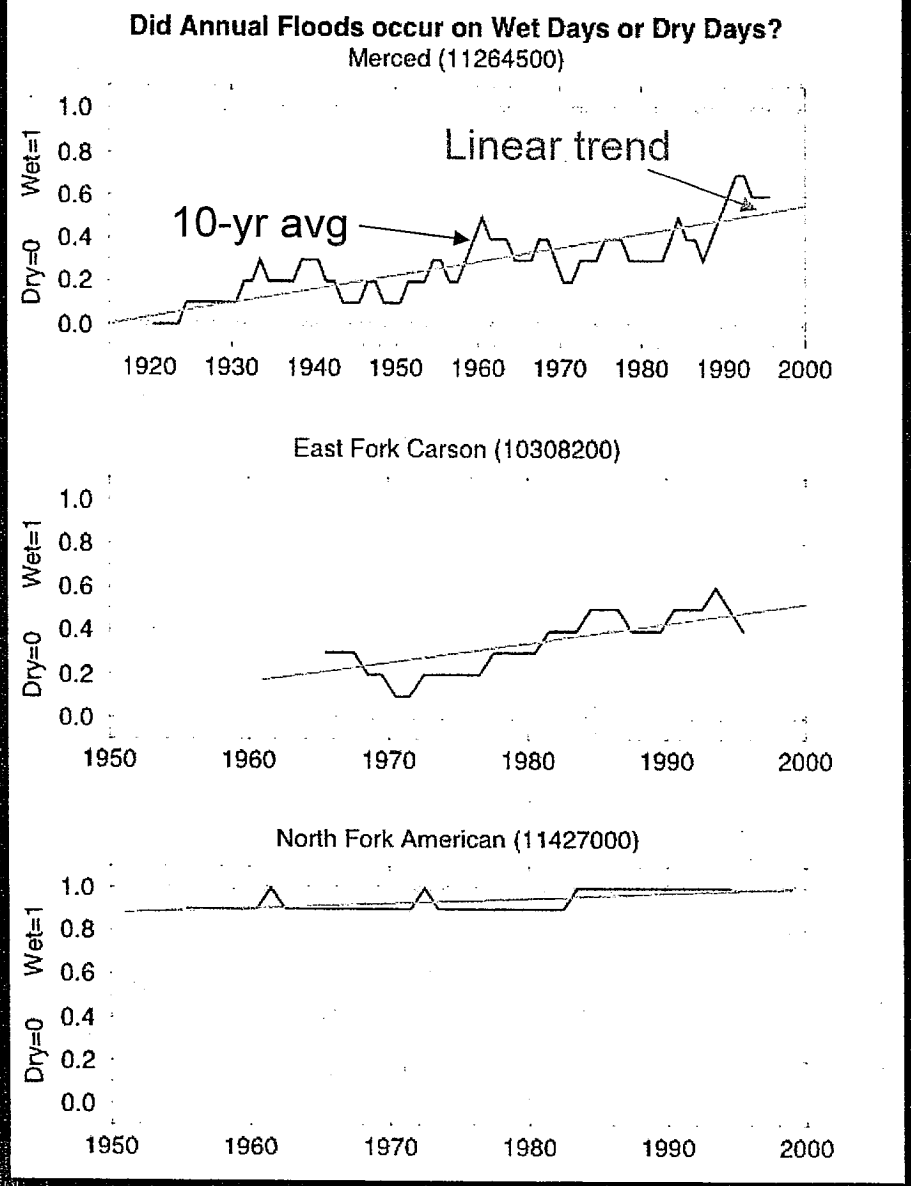


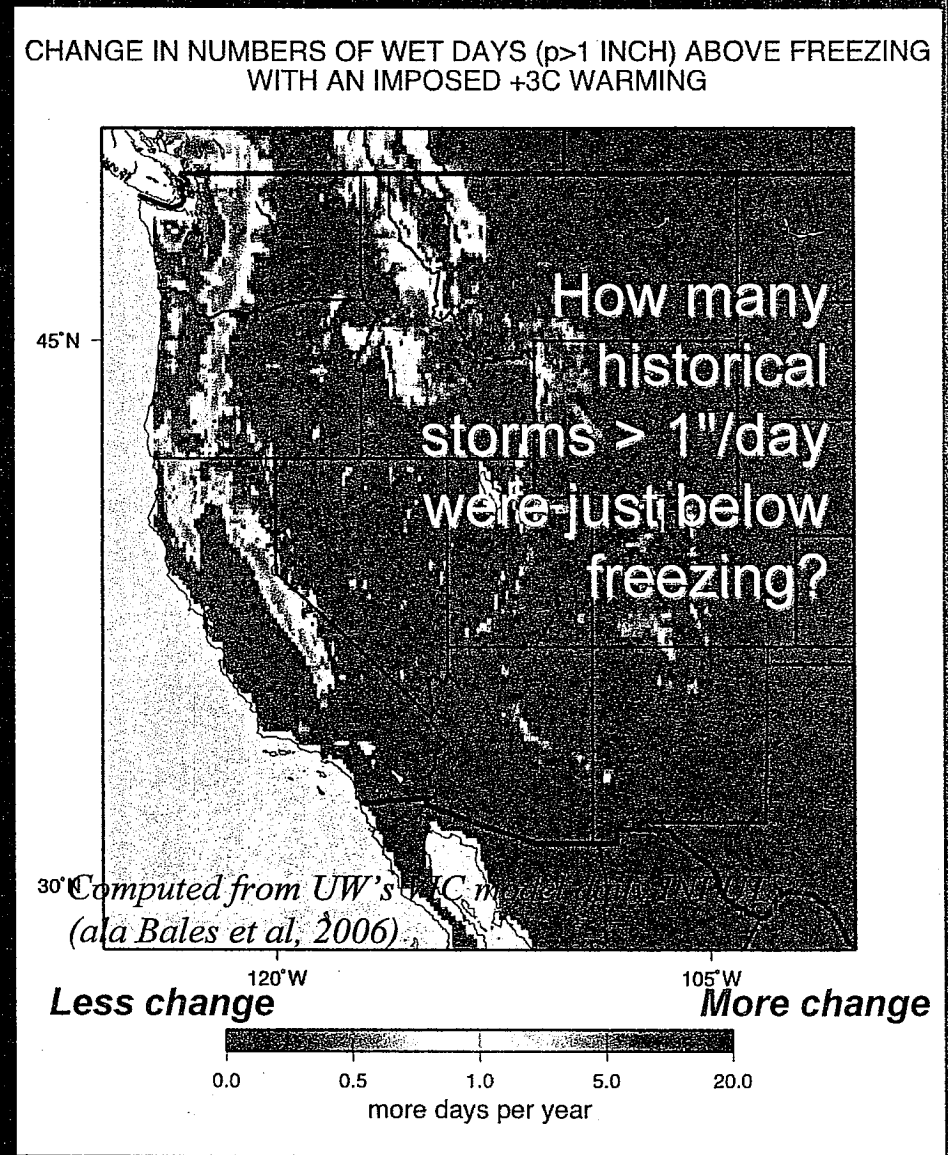
NUMBER OF HISTORICAL STORMS AMONG THE LARGEST 25
WITH TEMPERATURES IN RANGE: -3c TO 0c
[from 1950-1999 VIC 1/8-degree INPUT DATA]



Knowles and Cayan, 2004; http://www.fs.fed.us/psw/cirmount/ /meetings/agu/pdf2006/dettinger_etal_poster_AGU2006.pdf

If the warming continues, where should we expect the largest changes in warm-storm flooding to be manifested?

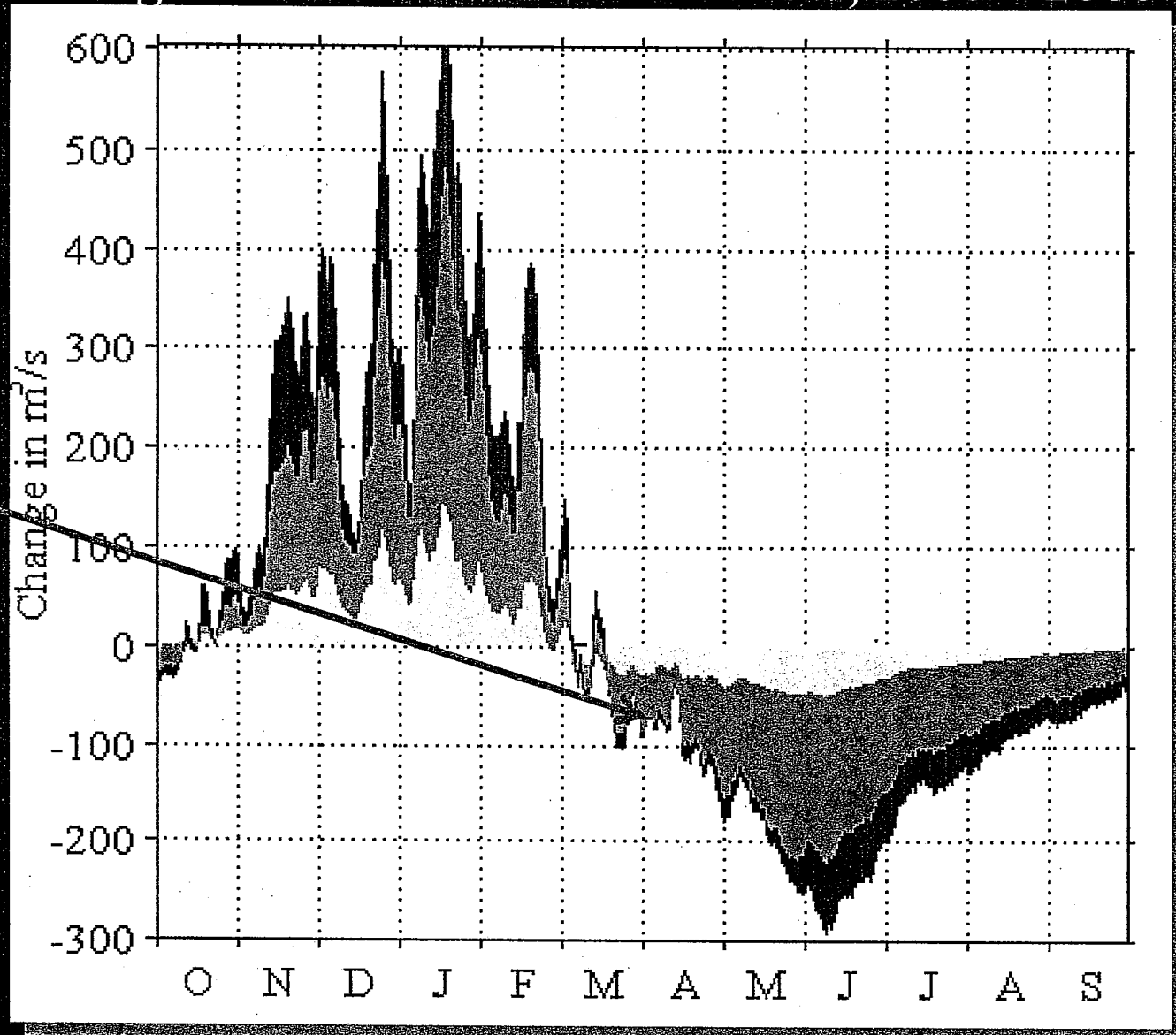




"Warm-storm flooding"

Changes in Sierra Nevada Outflow, 2060 – 2000

...and, with earlier runoff/ET and warmer summer temperatures,



Knowles and Cayan, 2004

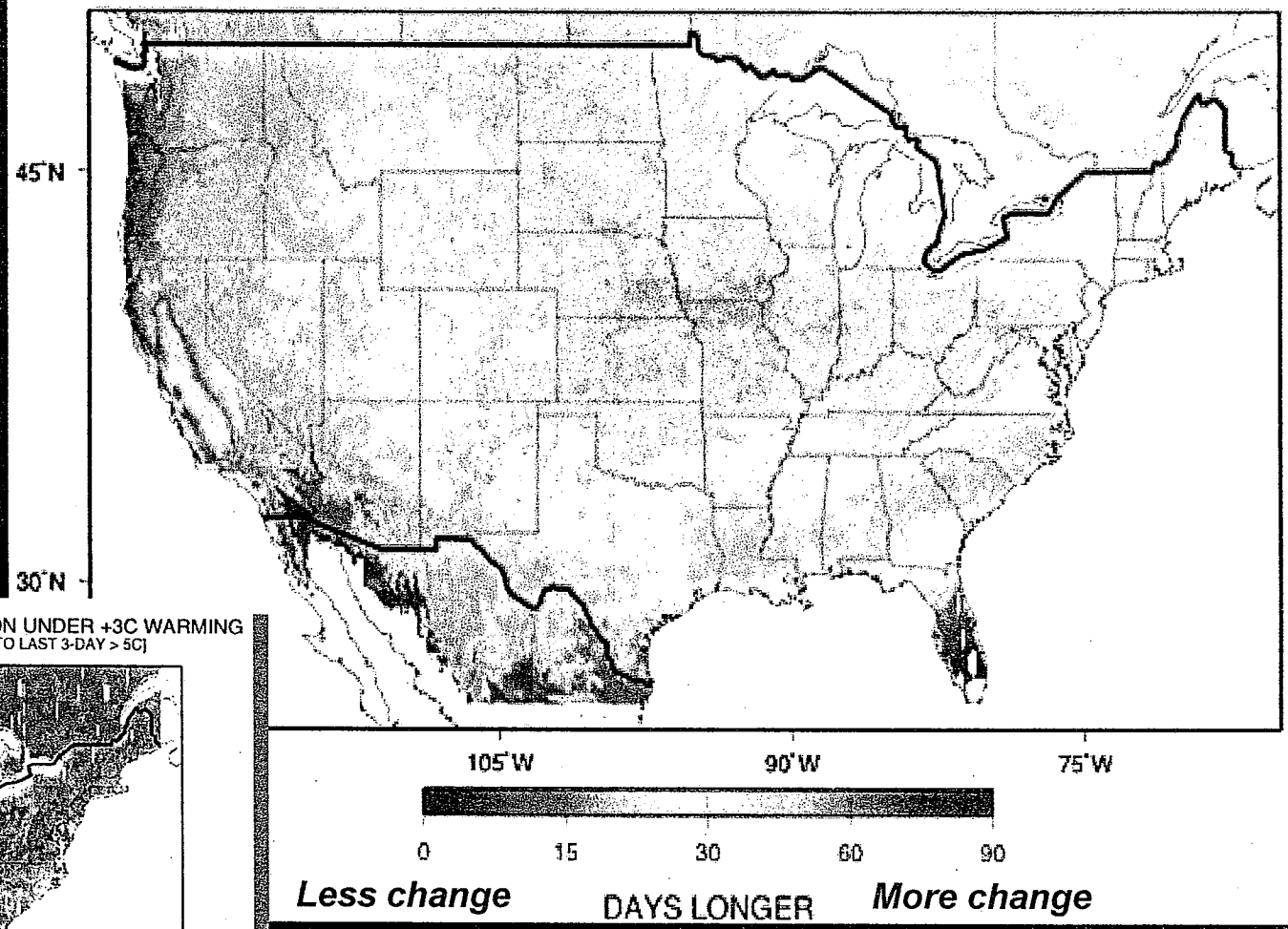
Dettinger et al., 2004

USGS

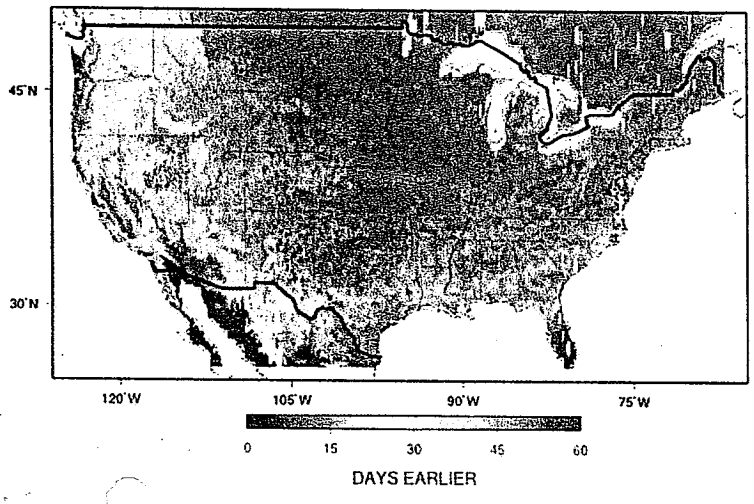
How much would a +3°C warming matter to GROWING SEASONS?

How many days historically were just below the onset temperatures for growing seasons ?

CHANGE IN GROWING-SEASON LENGTH UNDER +3C WARMING
[GROWING SEASON = LONGEST INTERVAL FROM FIRST TO LAST 3-DAY > 5C]



MEAN CHANGE IN BEGIN DATE OF GROWING SEASON UNDER +3C WARMING
[GROWING SEASON = LONGEST INTERVAL FROM FIRST TO LAST 3-DAY > 5C]



Growing Season Length

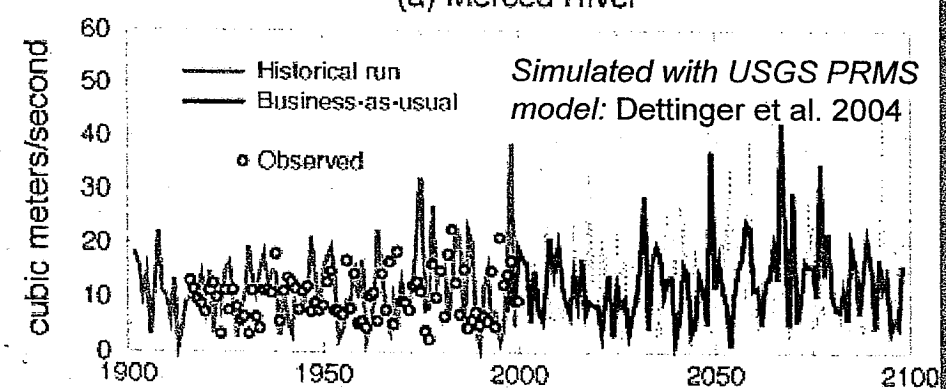
Computed from UW's VIC model daily INPUTS (ala Bates et al, 2006)

Overall, though, these seasonal-scale changes pretty much balance each other, so that runoff+recharge may not change much.

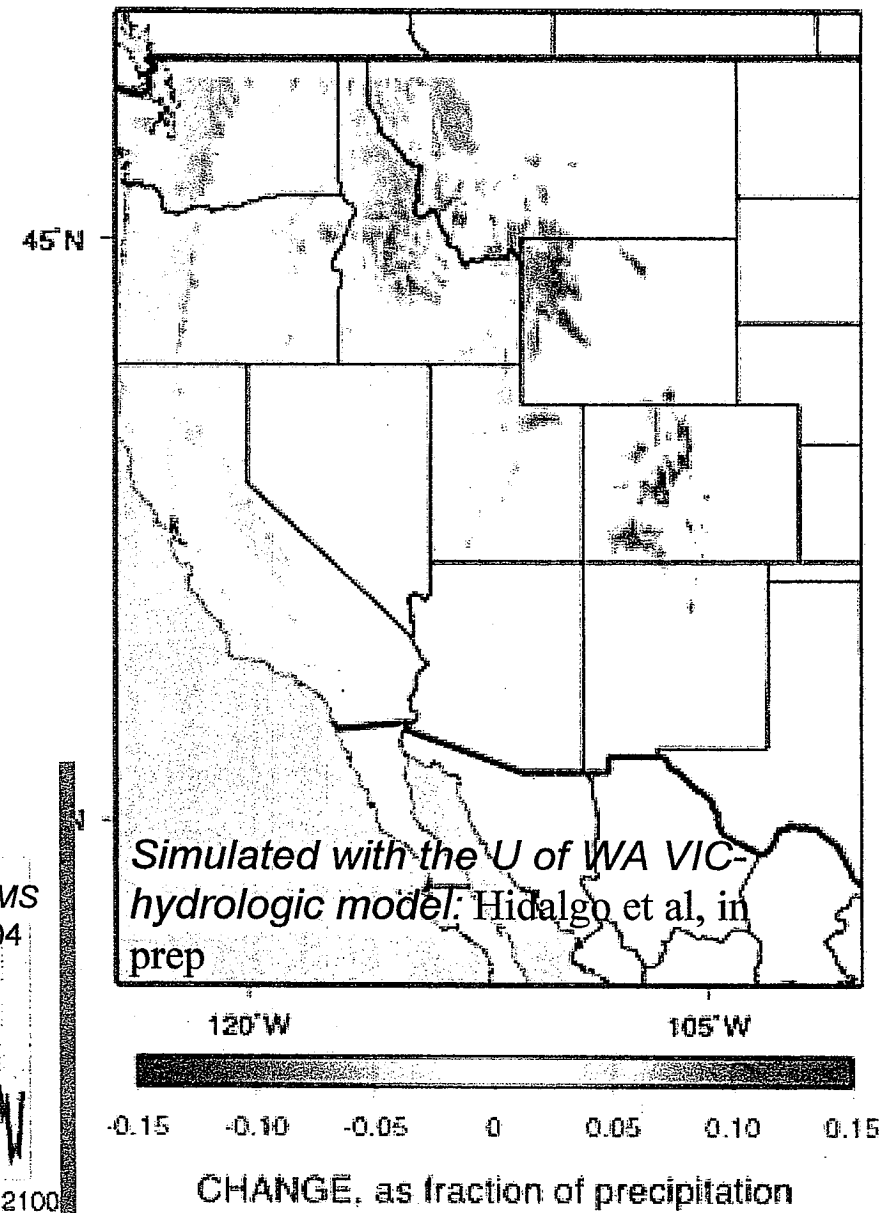
SIMULATED CHANGES IN RUNOFF+RECHARGE under a uniform +3°C warming

WATER–YEAR MEAN STREAMFLOWS

(a) Merced River

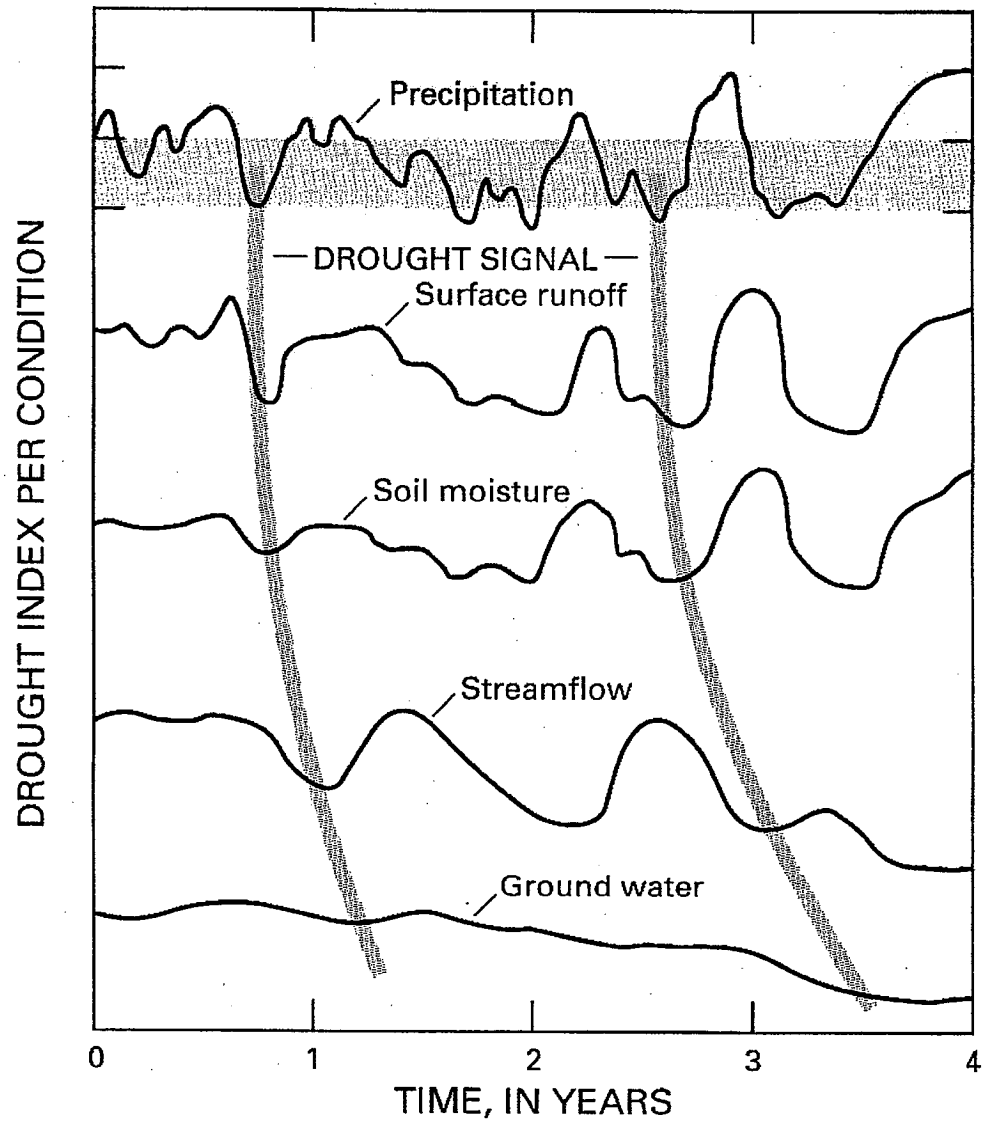


CHANGE IN PARTITIONING OF PRECIPITATION INTO OUTFLOW under +3C WARMING



Aquifers respond preferentially to lowest frequency climatic variations

This means that aquifers may express climate TRENDS disproportionately.

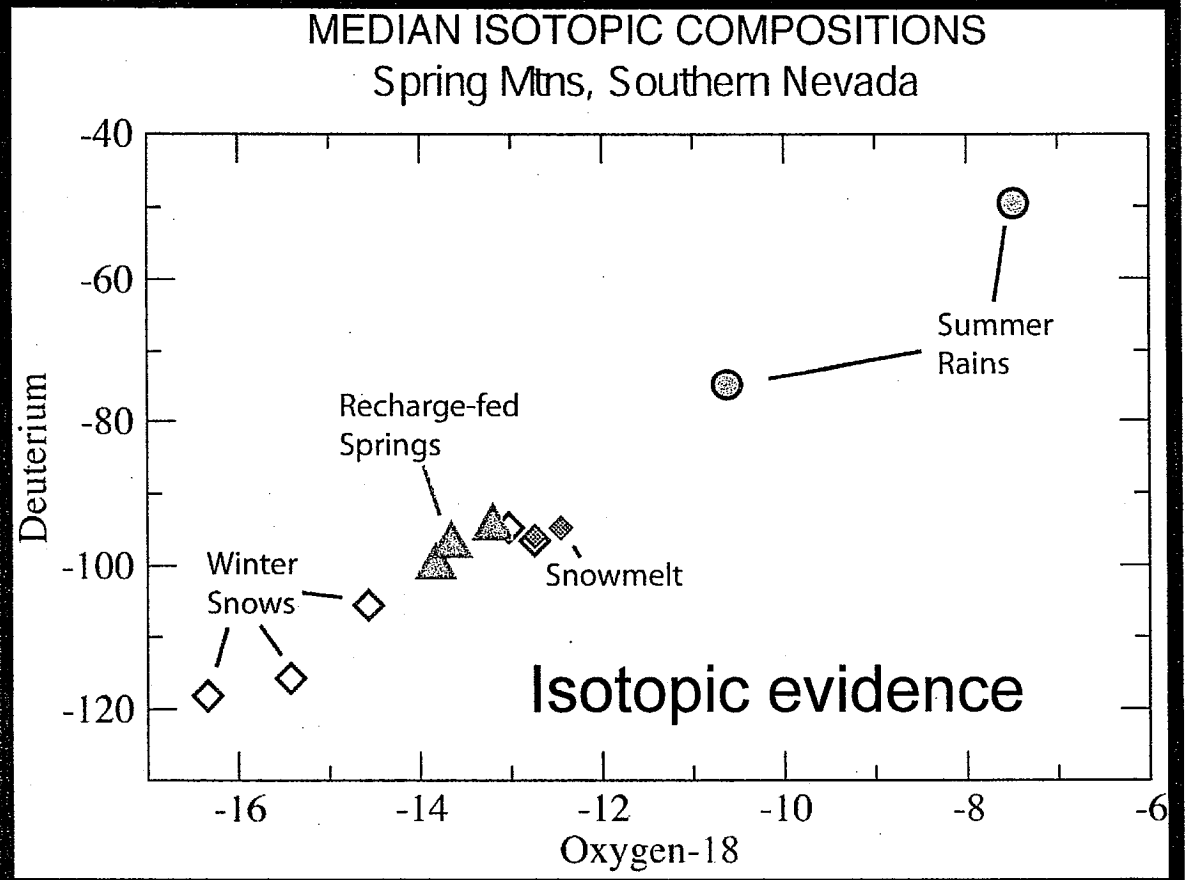


USGS

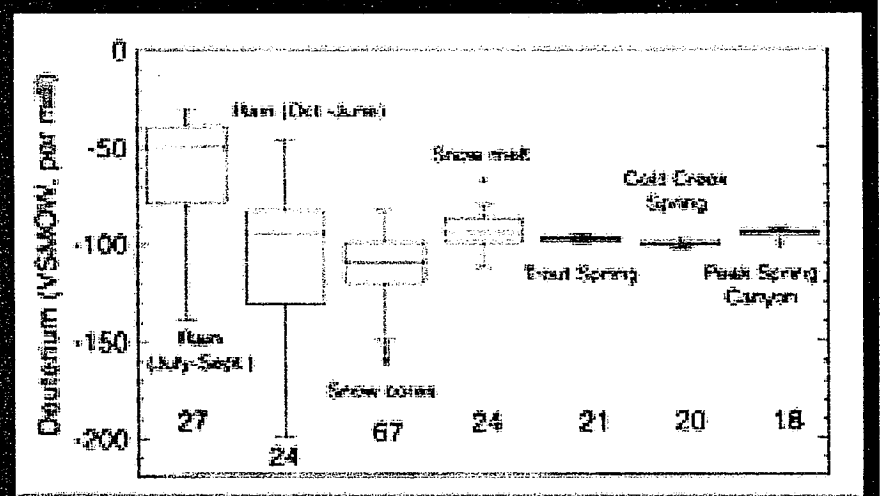
Changnon, 1987

In arid-semiarid zones, recharge comes preferentially from snowmelt.

An example from the Great Basin



Winograd et al., 1998

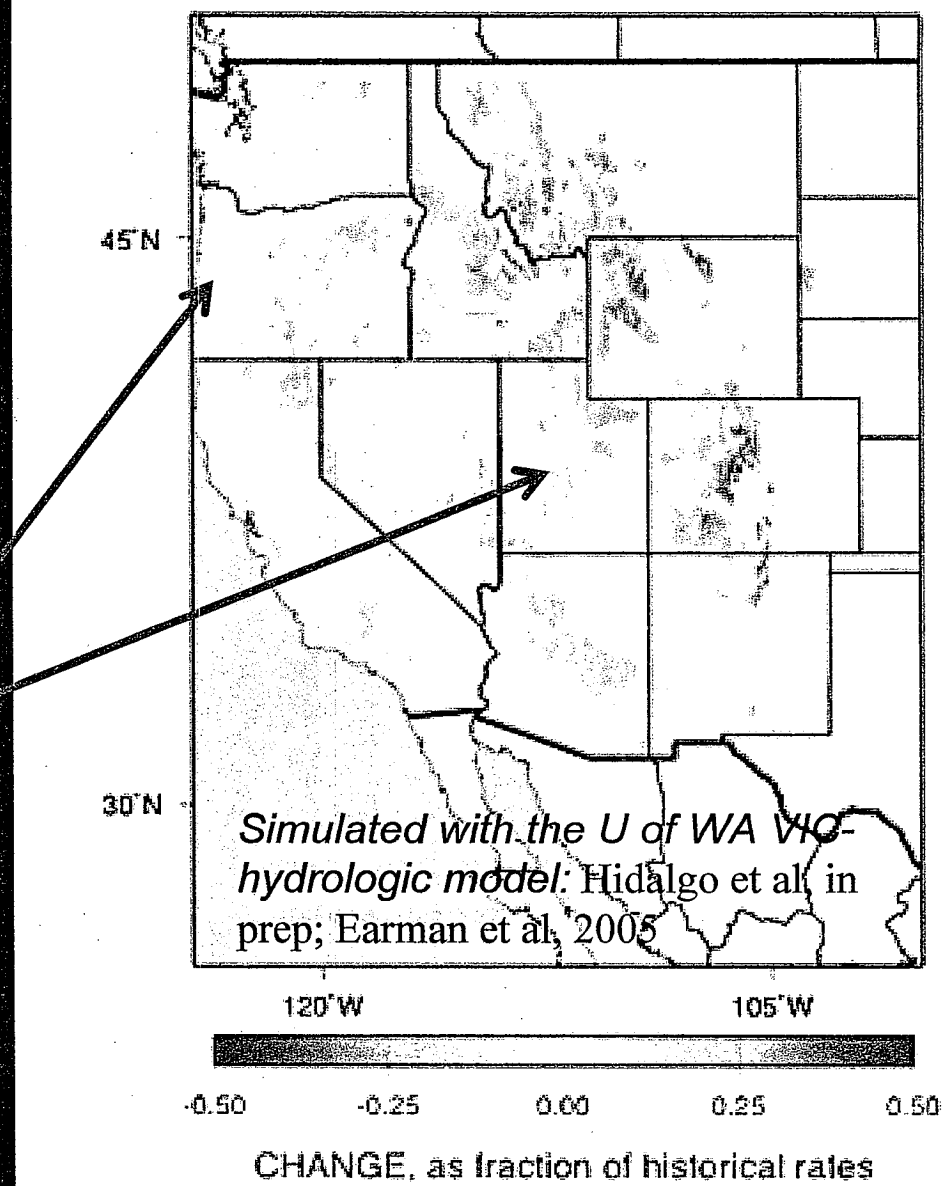


USGS

Thus, as snowpacks decline and rainfall takes over, RECHARGE may tend to decline in much of the West.

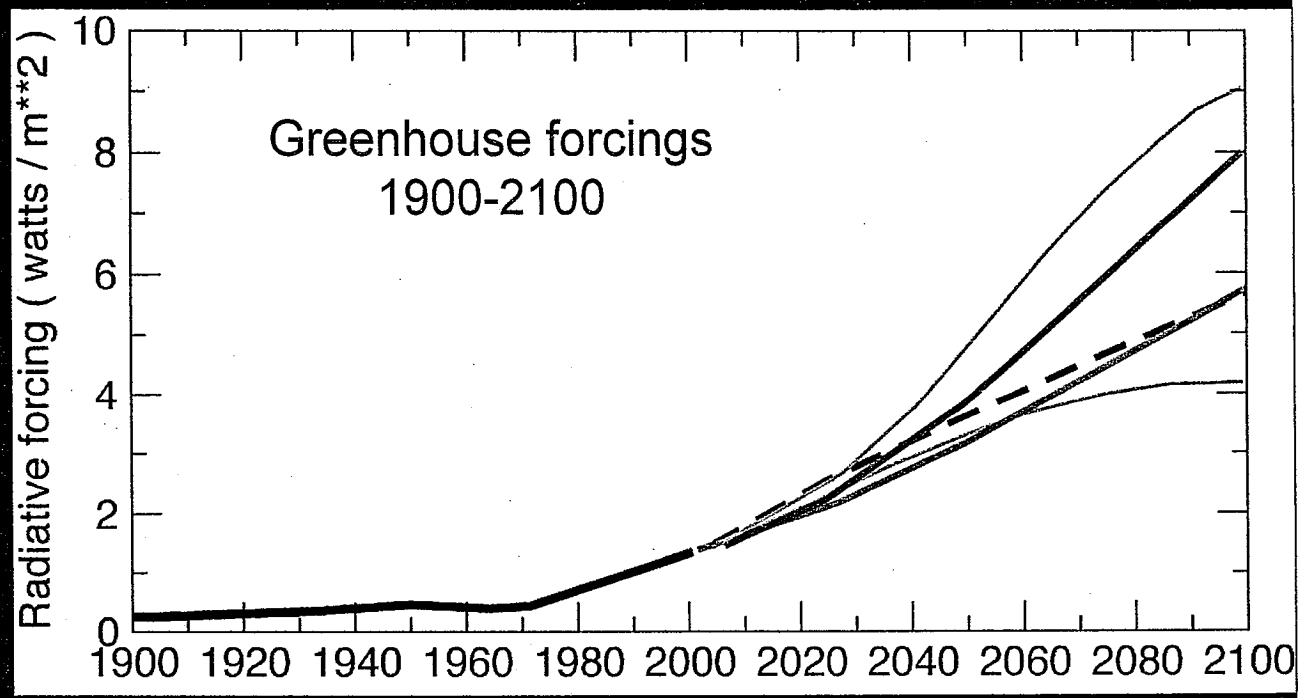
SIMULATED CHANGES IN RECHARGE under a uniform +3°C warming

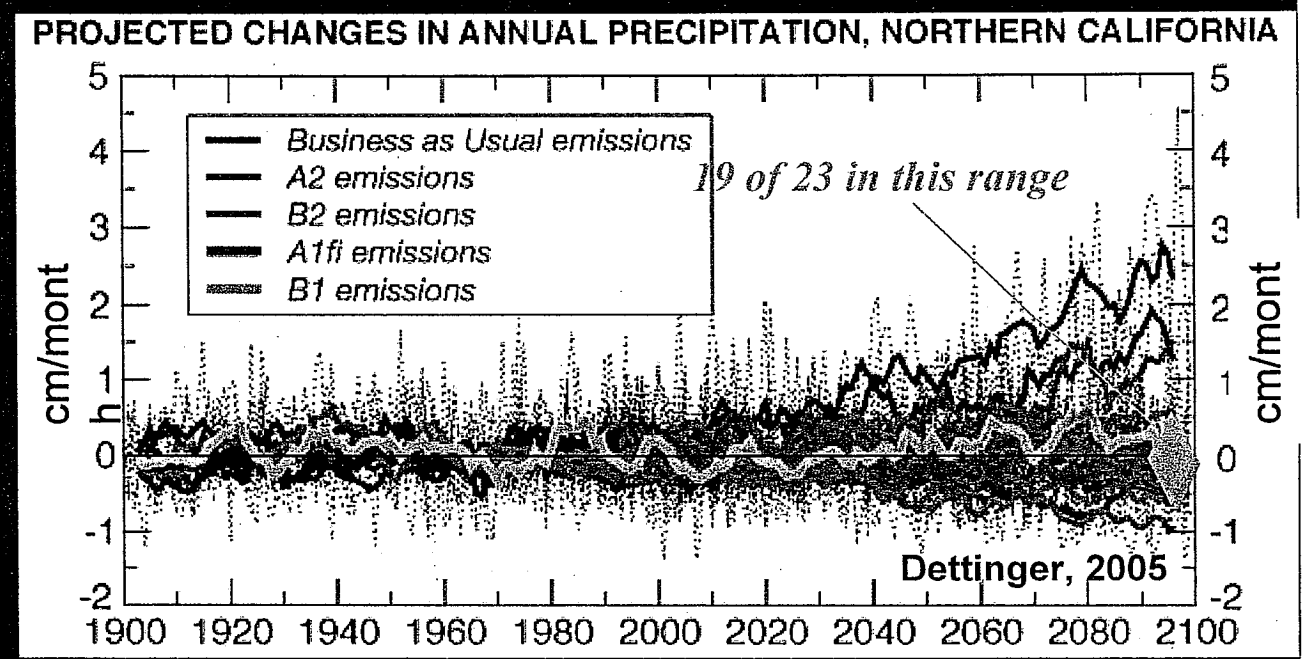
Widespread 15 to 25% changes projected, mostly as declines in recharge

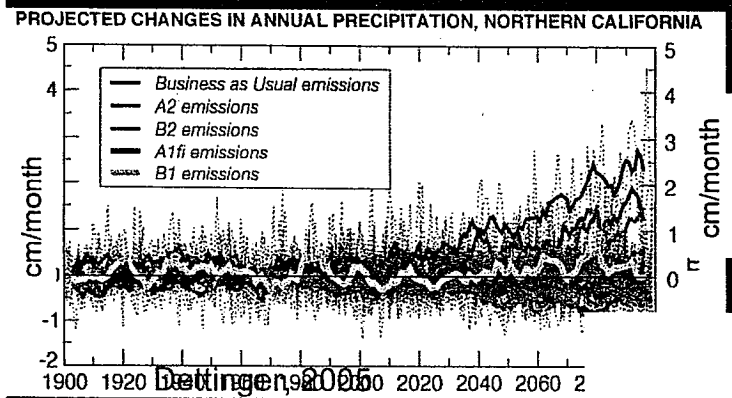


USGS

Under projected greenhouse forcings, most climate models yield a fairly narrow range of precipitation changes in California and most of the West.





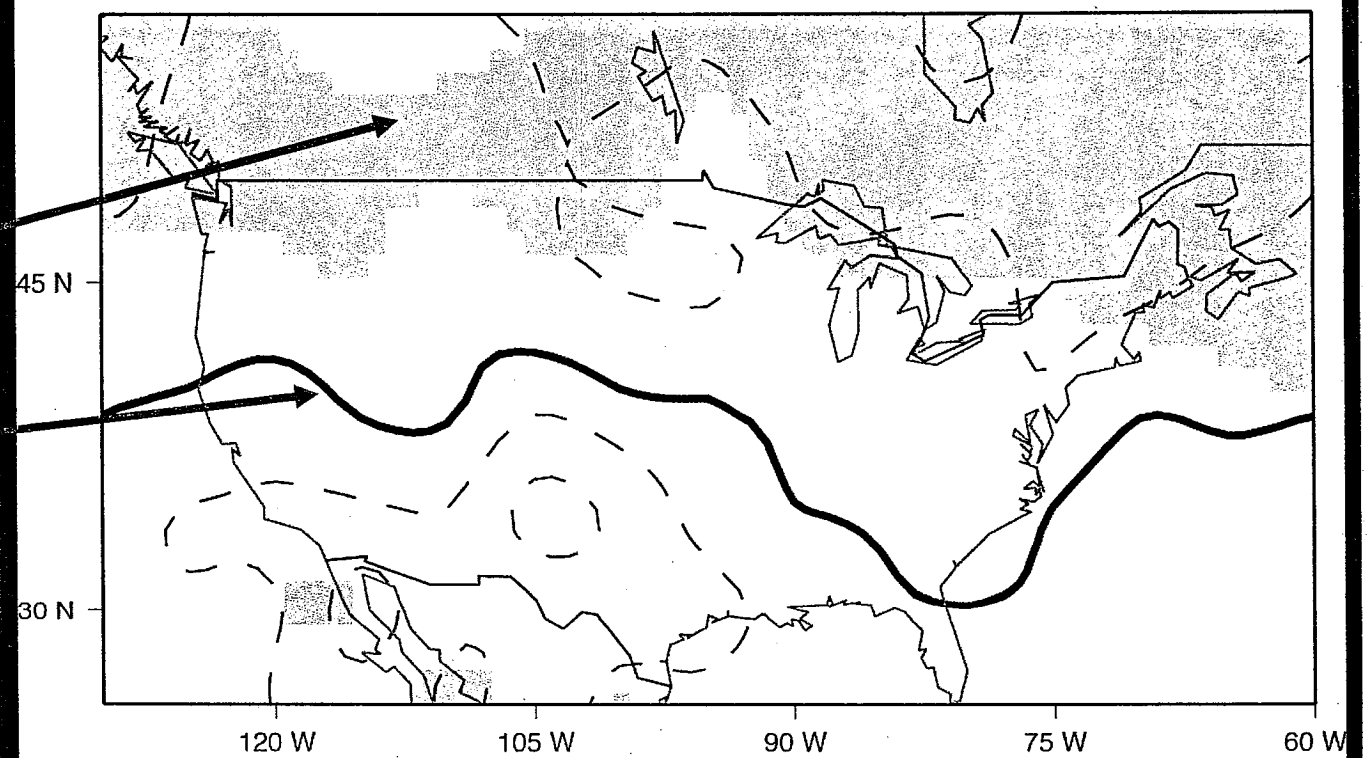


Dettinger, 2005

Across most of the central/north West, current climate models project small changes in precipitation. SW gets drier.

PRECIPITATION TRENDS FROM 13 MODELS

[IPCC 4TH ASSESSMENT (2007) A2 EMISSION SCENARIOS, 2001-2099]



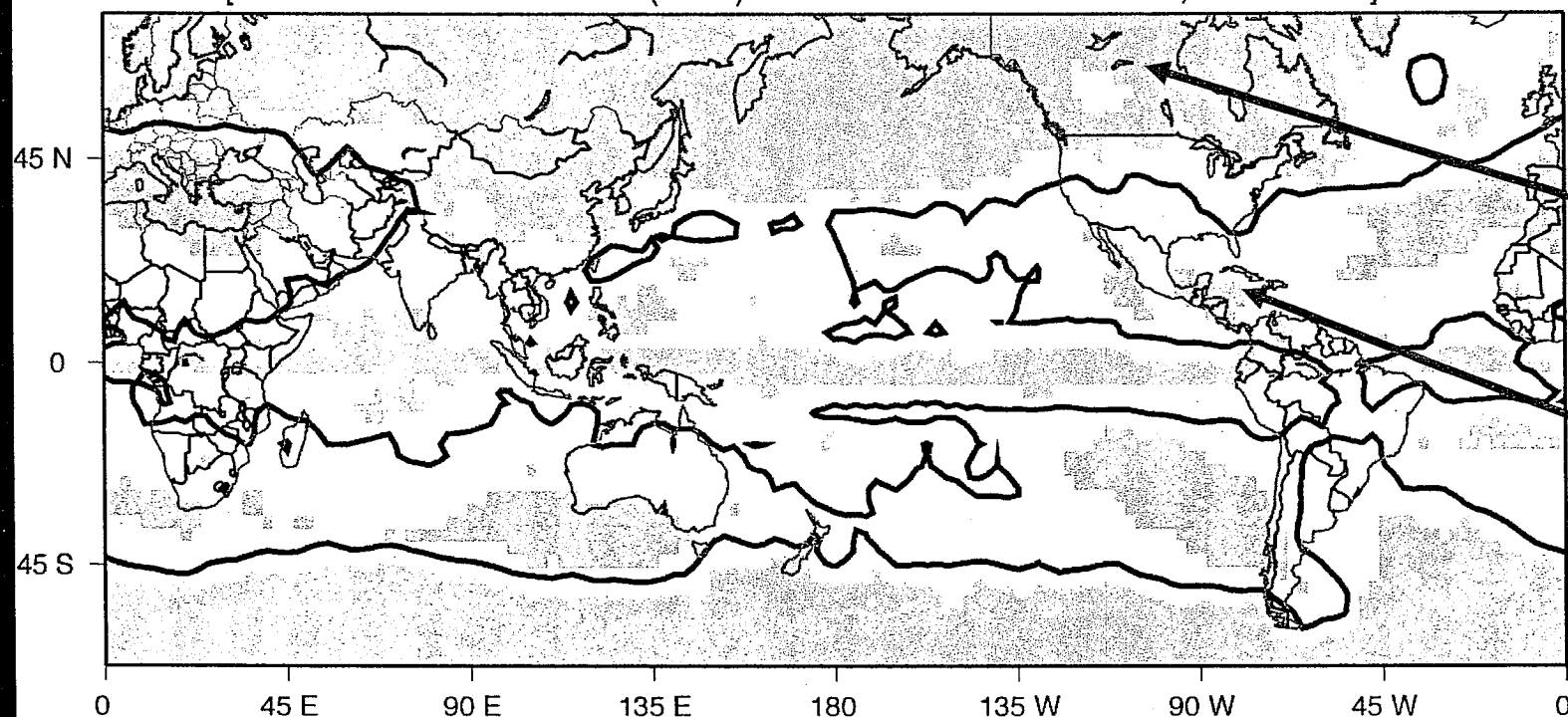
BLUE WHERE > 90% OF MODELS GET WETTER
RED WHERE > 90% OF MODELS GET DRIER

HEAVY CONTOUR WHERE HALF ARE WETTER, HALF DRIER
DASHED CONTOUR INTERVAL = 10% MEDIAN CHANGES

This is not an accident, but rather is part of a global pattern of projections of precipitation change.

CONSISTENCY OF PRECIPITATION TRENDS FROM 13 MODELS

[IPCC 4TH ASSESSMENT (2007) A2 EMISSION SCENARIOS, 2001-2099]



BLUE WHERE > 90% OF MODELS GET WETTER
RED WHERE > 90% OF MODELS GET DRIER
BOLD CONTOUR WHERE HALF ARE WETTER, HALF DRIER

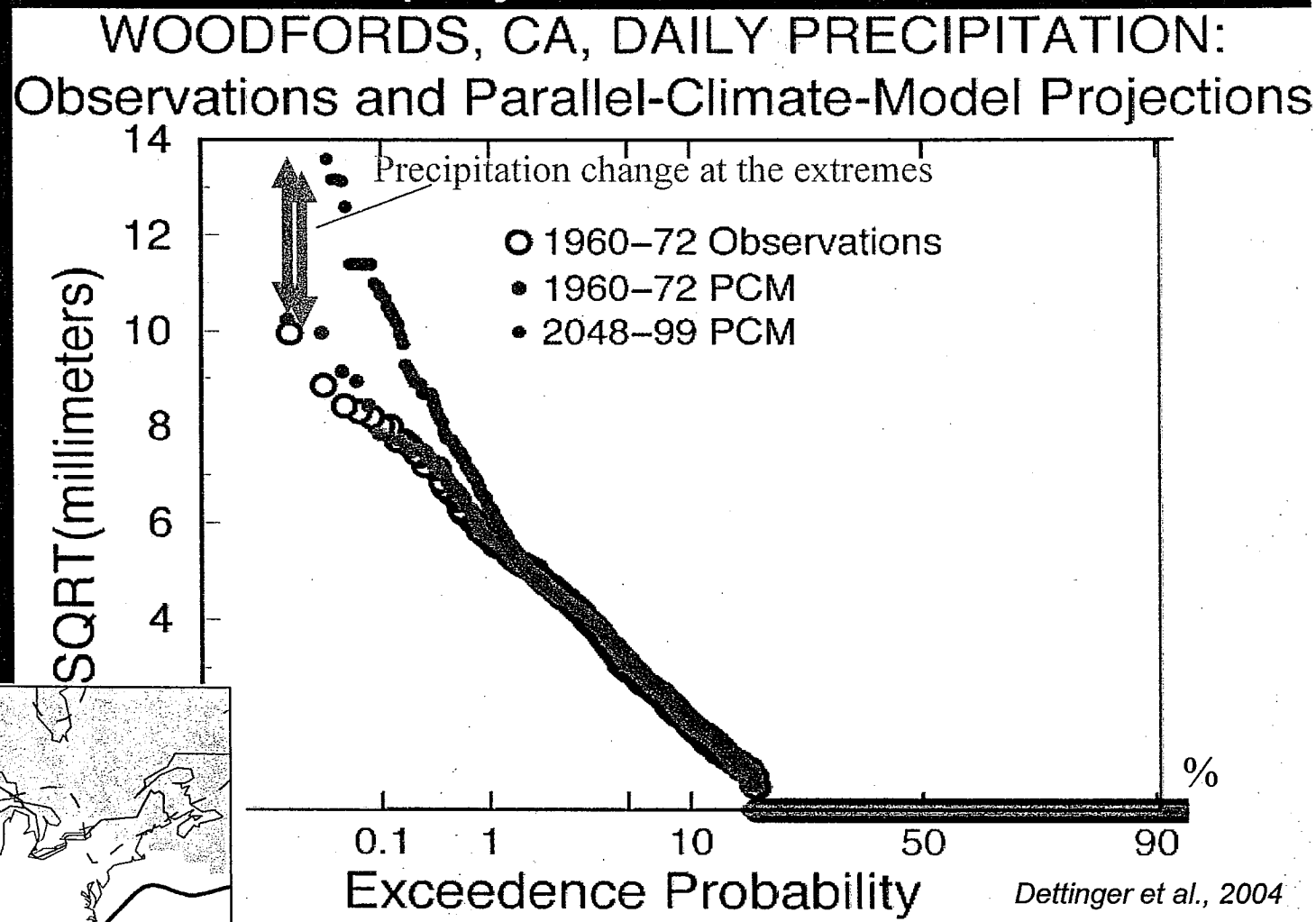
Poles and tropical oceans get wetter.

Subtropics get drier.

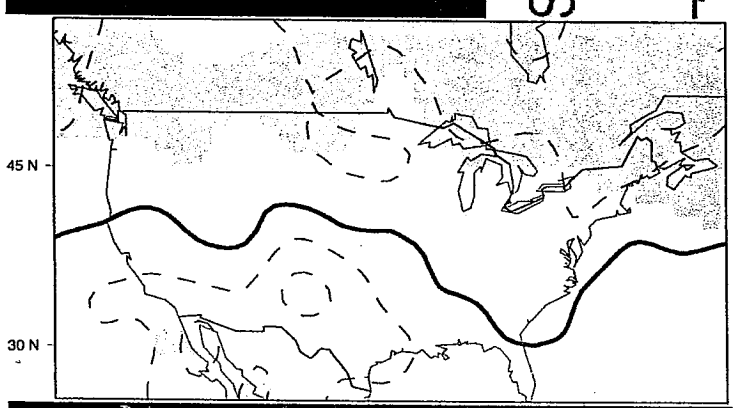
Most of conterminous US (& NV) somewhere in between.

However, with high-lats getting wetter and desert belts getting drier, the VARIABILITY of precipitation in middle latitudes is projected to INCREASE

Results from the US Parallel-Climate Model, 2001, which yields small changes in AVERAGE precipitation



Dettinger et al., 2004



TO SUMMARIZE…

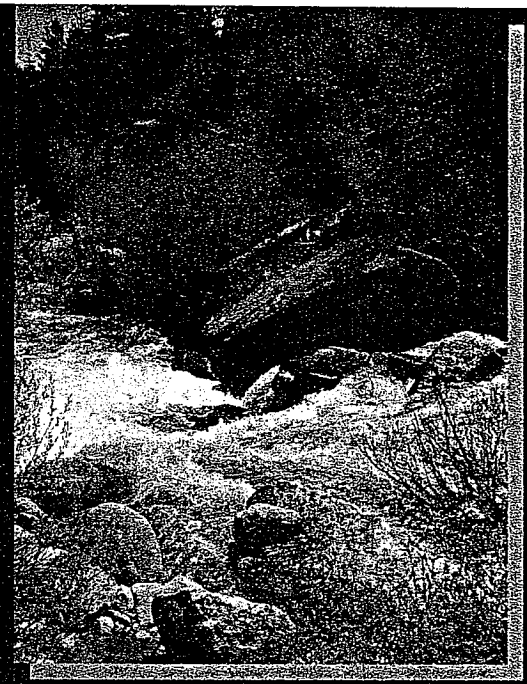
Warming by +2 to +6ºC,
likely more so at higher altitudes

Uncertain precipitation changes,
maybe more--maybe less, mostly small

Significant changes in

- rain-vs-snow storms
- snowpack amounts
- snowmelt timing
- flood risk
- streamflow timing
- low flows
- growing seasons
- recharge?

just in response to temperatures



"The most appropriate response to uncertainty is not denial; it is insurance."
--Prof. Michael Hanneman, UCB

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Carolee Krieger

From: "Michael Dettinger" <dettinge@cox.net>
To: <caroleekrieger@cox.net>
Sent: Thursday, March 22, 2007 4:29 PM
Attach: Dettinger_bren07_shared.ppt
Subject: slides from sustainability talk

Michael Dettinger.....voice: 858 822-1507
US Geological Survey.....fax:□□□858 822-2028
Scripps Inst of Oceanography.....http://tenaya.ucsd.edu/~dettinge
La Jolla, CA 92093-0224 USA.....mdettinger@ucsd.edu□□

All things are connected, like the blood that runs in your family...
The water's murmur is the voice of my father's father.
--Chief Seattle, 1854
----------Sent from USGS----------

Michael Dettinger.....voice: 858 822-1507
US Geological Survey.....fax:□□□858 822-2028
Scripps Inst of Oceanography.....http://tenaya.ucsd.edu/~dettinge
La Jolla, CA 92093-0224 USA.....mdettinger@ucsd.edu□□

"Anything else you're interested in is not going to happen if you□
can't breathe the air and drink the water. Don't sit this one out.□
Do something. You are by accident of fate alive at an absolutely□
critical moment in the history of our planet."--Carl Sagan
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OBJ

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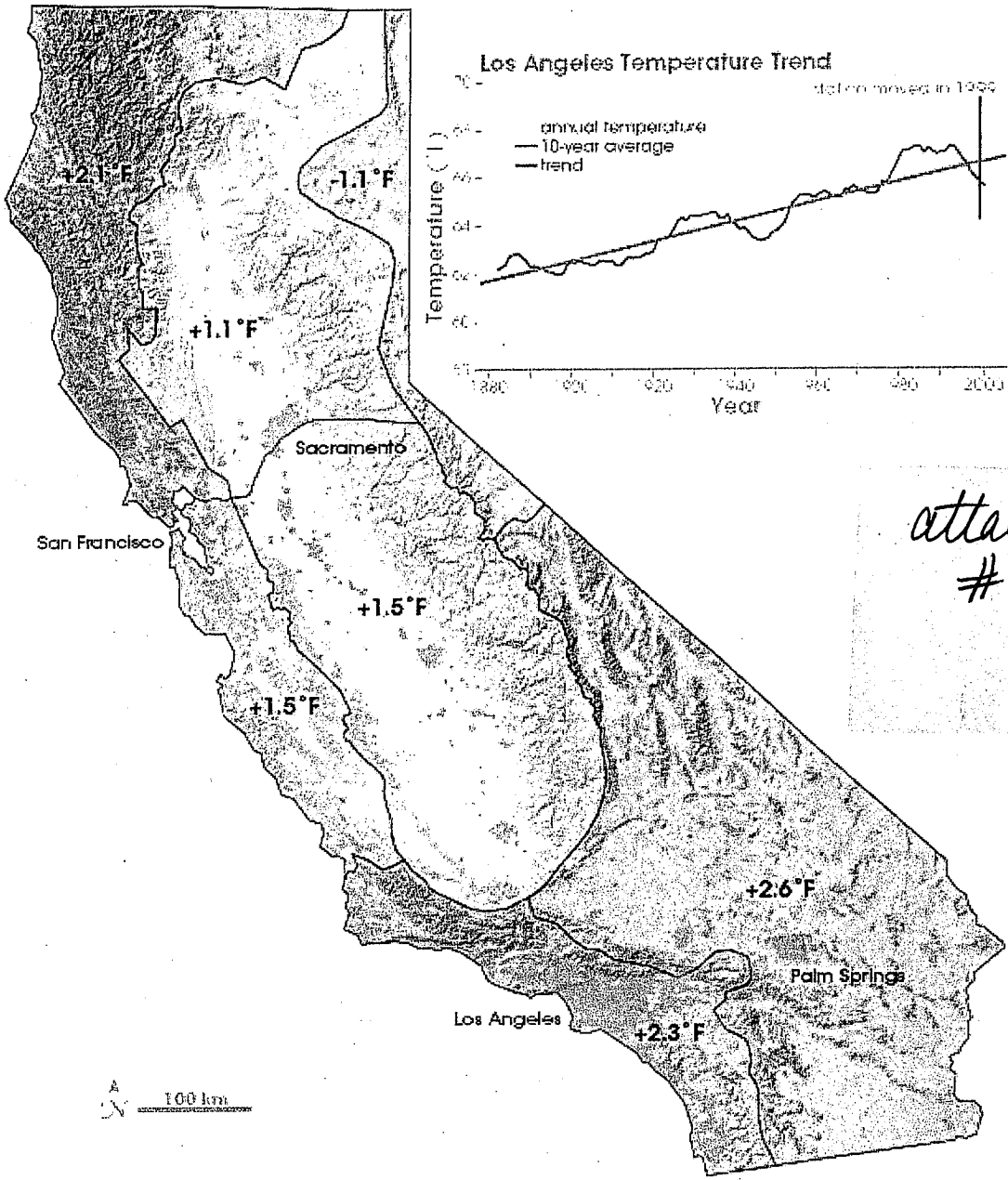
"Anything else you're interested in is not going to happen if you can't breathe the air and drink the water. Don't sit this one out. Do something. You are by accident of fate alive at an absolutely critical moment in the history of our planet."--Carl Sagan
----------Sent from home----------



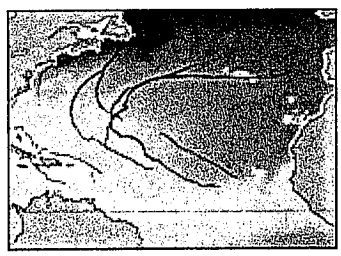
attachment #17

High-resolution Images

- Map (1.6 MB JPEG)
- Graph (110 kB PDF)

Average temperatures in California rose nearly two degrees Fahrenheit during the second half of the 20th century, with urban areas blazing the way to warmer conditions. When scientists at NASA and California State University, Los Angeles, analyzed observations from 331 weather stations between 1950 and 2000, they found that average temperatures rose in 6 out of 7 of the state's major climatic sub-regions. The scientists concluded that small increases measured in many rural areas may reflect the contribution of

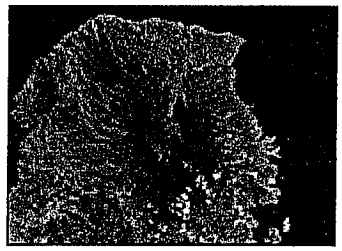
Latest Images
View Images Index



Dust Dampens Hurricane Formation

global warming due to rising greenhouse gas concentrations. Larger changes in and around urban areas are mostly due to growing population and the conversion of natural areas to urban ones.

Isles of Scilly, UK


Sumbawa, Indonesia

California's seven climate sub-regions are separated by black lines on the map. Regions where the average surface air temperature climbed less than 2 degrees are colored yellow, while areas where temperatures climbed more than 2 degrees are orange. The only region where temperatures dropped is colored light blue. Urban areas are colored gray. The greatest warming occurred in southern California's urbanized areas, including Los Angeles and rapidly growing Palm Springs. Urban areas raise average temperatures mostly by preventing an area from cooling off at night. According to one of the study's authors, NASA climatologist Bill Patzert, "California nights are heating up, giving us a jump start on hotter days."

For some California cities, temperature records go back to the late 19th century. The graph shows a record of temperatures in Los Angeles from 1878 through 2005. Gray bars show annual average temperatures, the black line shows the rolling 10-year average, and the blue line shows the warming trend. Average temperatures climbed from around 62 degrees to 66 degrees.

The drop in temperatures observed at the end of the 20th century resulted from the relocation of the official "downtown" Los Angeles station away from the more built-up part of the city to a more natural setting on the campus of the University of Southern California. The old site has so far remained operational, which gives scientists a chance to account for the impact of the move on long-term trends.

Further reading:

- Golden State Heating Up, New NASA/University Study Finds
- Urban Heat Island: Atlanta Georgia
- Beating the Heat in the World's Big Cities
- Urban Rain

NASA image adapted by Robert Simmon, based on data from Richard Medina, University of Utah (map), and Bill Patzert, NASA Jet Propulsion Laboratory (graph.)

Carolee Krieger

From: "Lloyd Carter" <lcarter0i@comcast.net>
To: "Linda Mitrovich" <lkm@solutionstrategies.com>; "Carolee Krieger" <caroleekrieger@cox.net>; "Dorothy Green" <dorgreen@adelphia.net>; "Joan Hartmann" <jrhartmann@impulse.net>; "Michael Jackson" <mjatty@sbcglobal.net>; <Tstokely@trinityalps.net>
Sent: Tuesday, April 17, 2007 4:56 PM
Subject: Emailing: EO Newsroom New Images - California Temperatures on the Rise

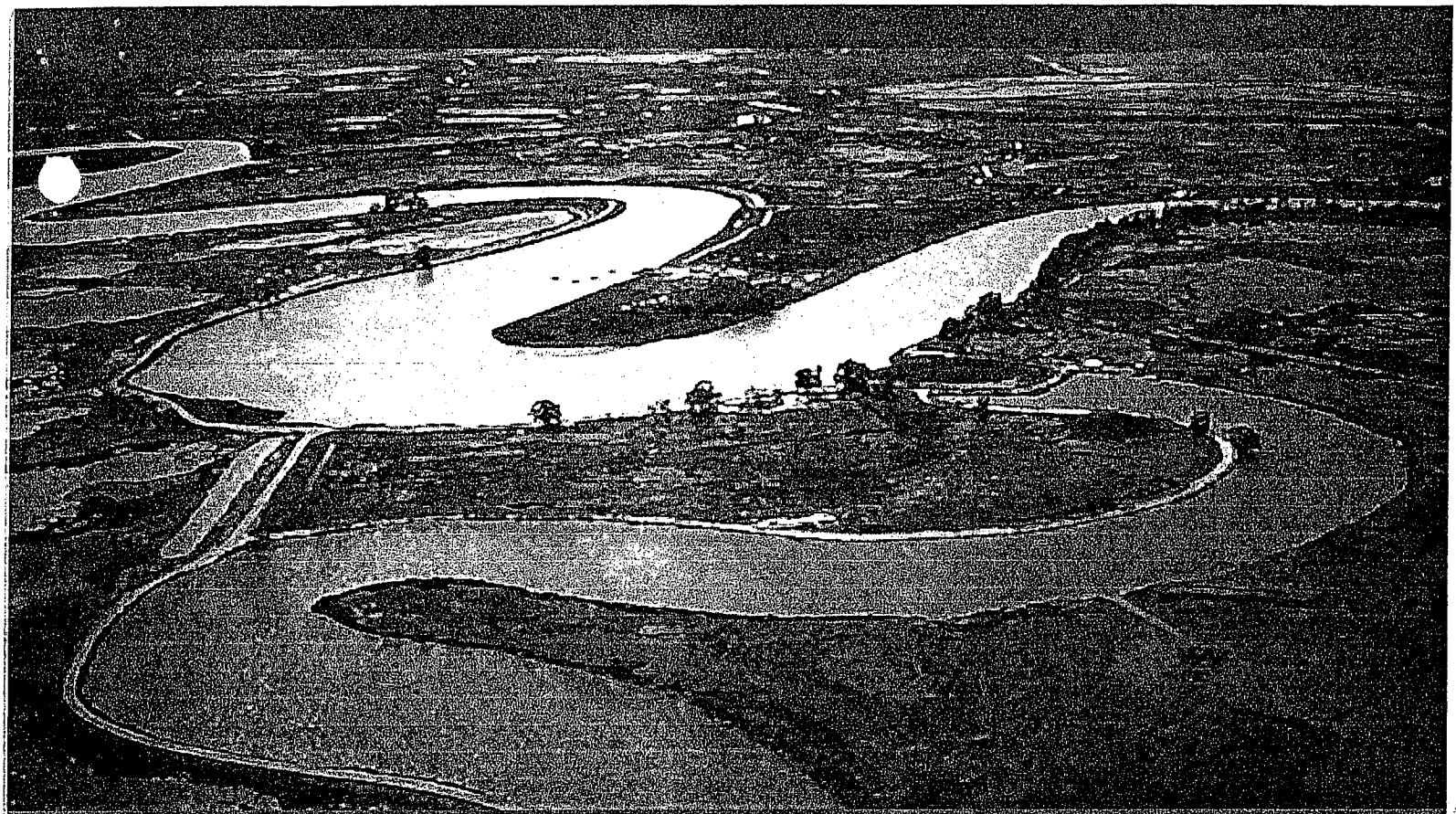
earth observatory

home • data & images • features • news • reference • missions • experiments • search

NEWS

NEW IMAGES

California Temperatures on the Rise



PELAGIC FISH ACTION PLAN

March, 2007

pg. 31

attachment #18

RESOURCES AGENCY

CALIFORIA DEPARTMENT OF WATER RESOURCES

CALIFORNIA DEPARTMENT OF FISH AND GAME

580
553
104
485
1,662

(1.662 MAF)

Status: *New.* The Planning Agreement for the BDCP dated October 6, 2006 has been signed by members of the Steering Committee and can be found at http://resources.ca.gov

Costs: For calendar years 2006 and 2007, Reclamation and DWR are contributing approximately $3 million annually for DFG, USFWS, and NMFS staff and administrative costs related to the development of the BDCP.

Water Project Operations

Jan 1 – Feb 15

- **Minimize Net Upstream Flows in Old and Middle Rivers from January to February 15th to 3,500 cfs, or 3,500-5,000 cfs (winter/early spring)** - *Limit the upstream (i.e. reverse or southward) net flow in Old River and Middle River to 3,500 cfs or 3,500-5,000 cfs from January through February 15, depending on water temperature and Sacramento River flow. Increased (more positive) ORMR flows may reduce adult delta smelt entrainment losses at the SWP and CVP intakes, and may also provide a better spawning distribution and reduce subsequent larval entrainment.*

  Status: *New.* The Delta Smelt Working Group (DSWG) reviewed this action and recommended its implementation to the Water Operations Management Team (WOMT). The WOMT approved this action in December 2006.

  Costs: Water costs may be highly variable depending on hydrologic conditions and export demand. Costs were estimated at the level needed to keep flows greater than 3500 cfs in Old and Middle Rivers. If the action were triggered in late December and continued through mid-February, the estimated maximum total water cost would be 580 TAF depending on the amount of export reduction needed to keep flows within the set parameters. 580,0

Mar 1 – ~~Feb~~ – april 15

- **Maintain Net Downstream Flow in Old River and Middle River Flows prior to the Vernalis Adaptive Management Program (VAMP) Period (early/late spring)** - *At least two weeks prior to VAMP, maintain net flows in Old and Middle Rivers at zero or positive (downstream or northward) to reduce entrainment losses of larval delta smelt. If March 1 14-day running average X2 position is east (upstream) of 65 kilometers (km), then trigger action when ripe or spent females are found in the Spring Kodiak Trawl (SKT) or within 10 days of Delta water temperatures reaching 12° C.*

  Status: *New.* The DSWG is reviewing this action. Recommendations on implementation will be forwarded to the WOMT for consideration and approval. The decision whether to implement an action would be made on a real-time basis dependent on the specific criteria and conditions for the potential action.

  Costs: Water costs may be highly variable depending on hydrologic conditions and export demand. Estimated water costs for an action during the first two weeks in April range from 35 TAF to 37 TAF. If the action were to extend back to March 1 and continued until mid-April, the estimated maximum total cost would be about 553 TAF 553,0

late May

- **No South Delta Barriers during VAMP and until June 1 (late spring)** - *Postpone installation of south Delta barriers until June 1 to reduce the proportion of water drawn towards the pumps from the central and south Delta in order to reduce entrainment losses of larval delta smelt.*

Status: *New.* The DSWG is reviewing this action, and recommended it for implementation to the WOMT. The WOMT is considering this action.

Costs: If this action delays ramping up of exports in late May, there may be costs associated with the action. The maximum estimated cost for two weeks in May would be about 104 TAF, and assumes the VAMP combined export level of 1,500 cfs would continue through May 31.

104,000

May–December

- **Maintain X2 West of Collinsville during May-December (summer/fall)** - *Increase Delta outflow to maintain an average X2 position west (seaward) of Broad Slough (80 km) near Collinsville from May through December to increase the amount of delta smelt habitat and shift it downstream. Winter entrainment may be reduced and food availability may be improved.*

Status: *New.* The DSWG is reviewing this action. Recommendations on implementation will be forwarded to the WOMT for consideration and approval.

425,0

Costs: This action is estimated to cost up to 425 TAF with most of the water costs occurring September-November. In below normal water years, the water costs would exceed 1 million acre-feet and such flows cannot be provided by storage releases without dramatic effects on storage levels and temperature conditions for fish upstream in the fall. Therefore, it is impractical to proceed with such flows in below normal and drier years.

1,000,

Food Web Actions

What are the water costs of these actions?

- **Provide Flows through Yolo Bypass into Cache Slough (summer)** -*Yolo Bypass has high primary productivity in summer, but net flows move upstream from Cache Slough. Increase summer flow connectivity from the bypass to downstream areas to provide for net downstream transport of productivity. Explore ways to add Yolo Bypass flows into Cache Slough during summer.*

Status: *New.* Implementation in the coming year is unlikely due to the need to develop specific plans, and permit and construct any physical modifications.

Costs: Costs are unknown at this time and would depend on the structural modifications needed.

- **Manage Flooding in North Delta for Seasonal Floodplain Habitat** – *Modify operations or land management to allow increased area and time of floodplain inundation in the Yolo Bypass and Cosumnes River floodplain. These actions would increase productivity of phytoplankton and zooplankton in order to support adults and egg production in fall, egg production in winter, and young delta smelt in spring and summer.*

Status: *Evaluating.* This action would likely require additional years to implement actions on the ground.

Costs: Overall costs are unknown. Planning and environmental review, including conceptual models, are estimated at $500,000.

- **Sherman Island Floodplain Phytoplankton Pilot Project** – *Pilot project to construct mile-long floodways on Sherman Island to emulate floodplains and increase primary production. Water will enter through screened inlets and be pumped out into Sherman Lake by fish-friendly pumps.*

Cons: Implementation of this action would place heavy demands on EWA water, and may exceed available assets if San Joaquin River inflows are in the typical range and export pumping rates are high.

This action has a high degree of scientific uncertainty because the relationship between net flow in Old and Middle Rivers and adult delta smelt salvage may not be linear. Average flow for the two months may not be the best predictor of salvage; antecedent conditions and events over shorter time periods in January and February may determine the outcome. The range of salvage is fairly wide at two-month average flows close to the selected target and at more negative flows. The migration behavior of delta smelt is not currently known (timing, destination).

If entraining fewer adult delta smelt results in more spawning in the southern Delta, entrainment of newly hatched delta smelt larvae may increase. No data are presently available to assess this potential outcome because these larval smelt are too small to be detected in current fish facility sampling. Avoiding upstream flow on Old and Middle Rivers once spawning has begun should increase the survival of larvae produced in the southern Delta. (See early/late spring action below)

Time to Implementation: This action has been approved for implementation by the WOMT. In general, this action would be initiated from January through mid-February unless the target flow conditions in Old and Middle Rivers are already satisfied. However, the action could be triggered and initiated as early as late-December 2006, and could end in mid-February 2007, depending upon river flows and exports. The decision whether to implement an action would be made on a real-time basis dependent on the specific criteria and conditions for the potential action.

Costs: Water costs may be highly variable depending on hydrologic conditions and export demand, and were estimated at the level needed to keep flows greater than -3500 cfs in Old and Middle Rivers. If the action were triggered in late December and continued through mid-February, the estimated maximum total water cost would be 580 TAF (ranging from 9 to 112 TAF per week) depending on the amount of export reduction needed to keep flows within the set parameters.

Maintain Net Downstream Flow in Old and Middle Rivers prior to the Vernalis Adaptive Management Plan (VAMP) Period (early/late spring)

At least two weeks prior to VAMP, maintain net flows in Old and Middle Rivers at zero or positive (downstream or northward) to reduce entrainment losses of larval delta smelt. If the March 1 14-day running average X2 position is east (upstream) of 65 kilometers (km), then trigger action when ripe or spent females are found in the Spring Kodiak Trawl (SKT) or within 10 days of Delta water temperatures reaching 12° C.

ORMR flows in March through May are primarily a function of San Joaquin River flow into the Delta and export pumping rate. Because San Joaquin River inflow is usually less than the export flow, ORMR flows are often in the reverse or upstream direction. With increasing upstream flows, there is increasing entrainment of delta smelt at the SWP and CVP pumps. The action is to maintain downstream (positive or northward) flow in Old and Middle Rivers once delta smelt spawning begins unless the March-April X_2 position in the Bay-Delta is seaward of 65 km. The action is focused on the first two weeks of April (just prior to the VAMP period), but could be started as early as March 1. Based on the start time, the action could extend over a two to six week period.

Implementation of this action would be triggered when ripe or spent female delta smelt are found in the SKT or within ten days of water temperature in the southern or central Delta increasing to12° C, the temperature at which delta smelt spawning is expected to begin. Ten days is about the time required for the attached eggs to hatch at this temperature, producing free-floating larvae which initially have very limited swimming ability. The action would likely not be necessary if on March 1 the 14-day running average X_2 position in the Bay-Delta is west (seaward) of 65 km because with this condition delta smelt would likely be distributed to the west and spawning would occur away from the influence of SWP and CVP pumping. The action would continue for at least two weeks, or if possible, until the start of the VAMP period (mid-April to mid-May). If these criteria are met, measures will be taken to maintain a downstream flow in Old and Middle Rivers utilizing increased San Joaquin flows or decreased exports at the SWP or CVP facilities.

Rationale: Favorable X_2 location during the spawning period reduces the exposure of delta smelt to effects of reverse flow in the southern Delta channels. With a less favorable X_2 location, avoiding upstream flow in Old and Middle Rivers once smelt have begun spawning in the central or southern Delta will reduce entrainment losses of larval smelt.

Combined particle tracking and 20 millimeter (mm) survey distributions suggest population losses are directly correlated with X_2 position and could reach an estimated 20-40% when X_2 moves landward of 60 km. Maintaining X_2 in a favorable location during the spawning period of delta smelt reduces their exposure to the effects of reverse flow in the southern Delta channels. If X_2 is in a less favorable location and delta smelt spawn within the Central and southern Delta, then avoiding upstream flow in Old and Middle Rivers once they have begun spawning will reduce entrainment losses of the smelt larvae. A favorable location for X_2 during this period is defined as seaward of 65 km based on a 14-day running average.

Delta smelt hatch dates back-calculated from otoliths (ear bones) indicate most fish surviving to summer-fall were hatched during the VAMP period when San Joaquin River flow is typically augmented, export pumping is relatively low and ORMR flows are from south to north (downstream). Ripe and spent adult smelt are commonly observed in the weeks and months prior to the VAMP period, so the scarcity of early-spawned smelt in fish sampling later in the summer or fall suggests either early spawning fish and/or their offspring experience high mortality, including loss from entrainment. If, as hypothesized by Bennett (unpublished data), early-spawned fish have high natural survival rates and potentially high reproductive value to the population, then their increased vulnerability to entrainment episodes may have important negative effects on the population.

Based on otolith strontium chemistry, in the POD years a relatively higher proportion of delta smelt surviving to summer/fall originated in the north and central Delta in recent years (Hobbs/Bennett, unpublished data) while contributions from other areas (e.g. Suisun Marsh) have declined for reasons yet to be determined. If persistence of the population depends increasingly on recruitment from the central Delta, then actions to minimize impacts of water management on survival of fish spawned in this area is warranted.

Pros and Cons:

Pros: Benefits include reduced entrainment of delta smelt, increased abundance and distribution of young delta smelt, and an increased percentage of larger, early-spawned fish. Avoiding upstream

flow on Old and Middle Rivers once spawning has begun should increase the survival of larvae produced in the southern/central Delta. The immediate positive effects on survival of delta smelt larvae seem likely. Whether there is a positive effect on age and size composition or abundance at later life stages, will depend on whether summer food conditions limit smelt population levels. Recent data suggest that summer food levels are limiting delta smelt abundance in the fall. Increasing the survival of delta smelt in the spring and early summer may not translate directly into increased fall population levels of delta smelt unless early hatching fish can survive through the summer.

Cons: Depending on water year and other actions taken, there may not be enough assets to maintain a positive flow in Old and Middle Rivers during this period.

Although the immediate effect on increasing the survival of delta smelt larvae seems likely, the scientific uncertainty of this action is medium-high. No data are presently available to assess this outcome directly because these larval smelt (less than 20 mm) are not detected in current fish facility sampling. The subsequent effect of this action on abundance depends on intervening factors later in the season, such as summer food limitation, which may diminish or override the benefits of this action.

In the post-VAMP period, inflow from the San Joaquin River usually decreases and diversions from the Delta increase. Salvage may increase at this time because the area of the Delta affected by pumping (zone of entrainment) expands as the pumping rate increases. Increased numbers of smelt in the salvage after the VAMP period may also be an indication of a larger post-larval and juvenile population in the affected portion of the Delta due to the benefits from prior action.

Time to Implement: This action can be implemented immediately upon a decision by WOMT. The decision whether to implement an action would be made on a real-time basis dependent on the specific criteria and conditions for the potential action. The action could be triggered on March 1, but would more likely be the first two weeks of April as a pre-VAMP action. The action could extend over a two to six week period depending on the start date.

Costs: Water costs may be highly variable depending on hydrologic conditions and export demand. Estimated water costs for an action during the first two weeks in April range from 35 TAF to 37 TAF. If the action were to extend back to March 1 and continued until mid-April, the estimated maximum total cost would be about 553 TAF (ranging from 35 to 108 TAF per week).

No South Delta Barriers during VAMP and until June 1 (late spring)

Postpone installation of south Delta barriers until June 1 to reduce the proportion of water drawn towards the pumps from the central and south Delta in order to reduce entrainment losses of larval delta smelt.

ORMR flows in March through May are primarily a function of San Joaquin River flow into the Delta and export pumping rate. Because San Joaquin River inflow is usually less than the export flow, ORMR flows are often in the reverse or upstream direction. With increasing upstream flows, there is an increasing entrainment of delta smelt at the project pumps. Under this action, no barriers in

the southern Delta would be operated during the VAMP period (typically April 15 to May 15), and thereafter until June 1. San Joaquin River flow and export pumping would be maintained according to VAMP protocol.

As part of the VAMP experimental design, a barrier is constructed at the head of Old River, where it begins at the San Joaquin River, to keep migrating young salmon in the San Joaquin River where survival is higher than if they move into Old River and the interior Delta. Three other temporary barriers are also constructed at other locations in nearby southern Delta channels. Together, these barriers dramatically alter flow patterns in the southern Delta, blocking the flow of water from the San Joaquin River through upper Old River to the CVP and SWP diversion facilities, so that more exported water flows from north to south in Old and Middle Rivers from the central Delta. During the 31-day VAMP period, combined SWP/CVP export pumping is relatively low, typically 1,500, 2,250 or 3,000 cfs per the VAMP design. Local agricultural diversions also operate at high rates in this season. Positive ORMR flows cannot be achieved unless the export flow is provided from the San Joaquin River via the upper reaches of Old and Middle Rivers.

Rationale: Recent particle tracking models (DSM-2) suggest the south Delta barriers substantially increase central and south Delta particle entrainment risk under VAMP conditions.

Combined particle tracking models and 20 mm survey distributions suggest population losses are directly correlated with X2 position and might reach an estimated 20-40% when X2 moves landward of 60 km. Maintaining X2 in a favorable location during the spawning period of delta smelt reduces their exposure to the effects of reverse flow in the southern Delta channels. A favorable location for X2 during this period is defined as seaward of 65 km during a 14-day running average.

Delta smelt hatch dates back-calculated from otoliths indicate most fish surviving to summer-fall were hatched during the VAMP period when San Joaquin River flow is typically augmented, export pumping is relatively low, and ORMR flows are from south to north (downstream). Ripe and spent adult smelt are commonly observed in the weeks and months prior to the VAMP period, so the scarcity of early-spawned smelt in fish sampling later in the summer or fall suggests either early-spawning fish and/or their offspring experience high mortality, including loss to entrainment. If, as hypothesized by Bennett (unpublished data), early-spawned fish have high natural survival rates and potentially high reproductive value to the population, then their increased vulnerability to entrainment episodes may have important negative effects on the population.

Based on otolith strontium chemistry, in the POD years a relatively higher proportion of fish surviving to summer/fall originated in the north and central Delta in recent years (Hobbs and Bennett, unpublished data) while contributions from other areas (e.g. Suisun Marsh) have declined for reasons yet to be determined. If persistence of the population depends increasingly on recruitment from the central Delta, then actions to minimize impacts of water management on survival of fish spawned in this area is warranted.

Pros and Cons:

Pros: Benefits include reduced entrainment of larval delta smelt, increased abundance and distribution of young delta smelt, and an increased percentage of larger, early-spawned fish.

Avoiding upstream flow on Old and Middle Rivers once spawning has begun should increase the survival of larvae produced in the southern and central Delta.

The immediate positive effects on survival of delta smelt larvae, until the early summer survey, seems likely. However, a positive effect on age and size composition, or abundance at later life stages, will depend on whether summer food conditions for delta smelt limit smelt population levels. Recent data suggest that summer food levels are limiting delta smelt abundance into the fall, and the increase in delta smelt in the spring and early summer may not translate directly into increased fall population levels of delta smelt.

Cons: This action has a medium-high degree of scientific uncertainty. The barrier at the head of Old River is presently utilized to increase survival of Chinook salmon smolts migrating out of the San Joaquin Basin. The other barriers are used to help maintain water levels in the southern Delta to prevent cavitation of agricultural diversion pumps. Postponement of barrier installation would conflict with these purposes.

Time to Implement: Agreement to implement this action may take some time in order to resolve issues regarding the use of these barriers. This action would be implemented during the 31-day VAMP period starting on or about April 15. The barriers addressing local agricultural diversion would not be fully installed until June 1.

Costs: If this action delays ramping up of exports in late May, there may be some costs associated with the action. The maximum estimated cost for two weeks in May would be about 104 TAF (ranging from 26 to 52 TAF per week), and assumes the VAMP combined export level of 1,500 cfs would continue through May 31.

Maintain X_2 West of Collinsville during May-December (summer/fall)

Increase Delta outflow to maintain an average X_2 position west (seaward) of Broad Slough (80 km) near Collinsville from May through December to increase the amount of delta smelt habitat and shift it downstream. Winter entrainment may be reduced and food availability may be improved.

Through a combination of increased upstream releases and decreased project exports, the X_2 position is maintained seaward of Broad Slough during May-December. This action might be implemented if the current water year type is "above normal" or wetter, which is largely determined by precipitation and runoff in the previous winter and spring. This action would not be considered for implementation if the water year is a "below normal" or drier year because water costs would exceed 1 million acre-feet, and such flows cannot be provided by storage releases without dramatic effects on storage levels and temperature conditions for fish upstream in the fall.

Rationale: Higher Delta outflow in the summer and fall can increase the amount of habitat for delta smelt. If smelt use this habitat and their distribution is wider and shifted downstream, subsequent entrainment in the winter will be reduced.

Pros and Cons:

Pros: Benefits may include an improved Environmental Quality Index, wider geographic distribution of delta smelt, decreased larval and adult delta smelt entrainment at project pumps, and an increased percentage of early-spawned fish. Food availability may also be improved resulting in improved survival and health of the fish.

Cons: Water assets could be difficult to provide. The scientific uncertainty of this action is high. The effectiveness of this action depends on fish behavior in reaction to changed habitat conditions, and most responses pertaining to increased population numbers are expected well after the period of action implementation. Post-VAMP delta smelt salvage may increase if Delta inflow from the San Joaquin River decreases and diversions increase because the zone of entrainment expands and the post-larval and juvenile population may be larger due to the positive effects of prior actions.

Time to Implement: Once the management decision is made, and if assets are available, implementation can occur almost immediately.

Costs: This action is estimated to cost up to 425 TAF with most of the water costs occurring September-November. In below normal water years, the water costs would exceed 1 million acre-feet and such flows cannot be provided by storage releases without dramatic effects on storage levels and temperature conditions for fish upstream in the fall. Therefore, it is impractical to provide such flows in below normal and drier years.