PROGRESS REPORT
STORAGE AND CONVEYANCE REFINEMENT PROCESS

BACKGROUND

Phase I of the CALFED Bay-Delta Program (Program) defines the program mission, objectives, and three general alternatives. The mission of the Program is to restore ecological health and improve water management for beneficial uses of the Bay-Delta system. The approach is to concurrently address problems in four resource areas:

- Water Supply Reliability (includes water use efficiency and water transfers)
- Water Quality
- Levee System Integrity, and
- Ecosystem Quality

The three alternatives developed in Phase I are differentiated by how they address the issues of Delta conveyance and type and amount of system storage.

The three concepts for Delta conveyance are:

- Alternative 1: More efficient use of the existing system of conveyance
- Alternative 2: Modified through-Delta conveyance
- Alternative 3: Dual conveyance using both through-Delta and isolated conveyance facilities

Each alternative includes varying configurations of system storage, including groundwater banking, in-lieu conjunctive use, and more surface storage capacity. These include storage upstream of the Delta on the tributaries of the San Joaquin River and Sacramento River systems, storage within the Delta itself, or storage connected to the SWP or CVP export aqueducts (historically referred to as south of Delta storage but for the purposes of this report referred to as aqueduct storage to differentiate it from storage on the San Joaquin River system).

CONSIDERATIONS FOR STORAGE AND CONVEYANCE DEVELOPMENT

The number of potential combinations of storage and conveyance facilities is too great to analyze each individually. Just as important, there is a wide range of operating rules for managing any new facilities. The challenge has been to find a reasonable number of configurations which can represent the range of options for evaluation at a programmatic level.

Phase II of CALFED Bay-Delta Program includes the following considerations that affect the storage and conveyance refinement process:

- **Component Refinement and Prefeasibility Analyses**. Sufficient analysis of conveyance concepts and potential storage sites must be completed to identify impractical and overly expensive options. In particular, over the long term, the alternative selection process must comply with Section 404(b)(1) of the Clean Water Act to the satisfaction of the Corps of Engineers and the EPA. This implies that in the short term, the storage and conveyance refinement process must comply with those requirements and that potential environmental impacts must be identified and given due consideration in the refinement and prefeasibility process.

- **Completion of the Programmatic EIR/EIS**. The EIR/EIS will include descriptions of potential impacts, define strategies for mitigation of those impacts, and document the selection of the preferred alternative. The alternatives will be defined in terms of general solution strategies and ranges of facility capacities. However, despite their programmatic nature, these ranges need to be founded on solid scientific and engineering information.

- **Collaborative Process**. CALFED agencies and stakeholders must have sufficient access to the process to be assured that the selected alternative is not only legally defensible, but generally meets the solution principles.

- **Focused Schedule**. All this work must move quickly, because the numerous technical, legal, biological, and institutional studies needed to complete the process become obsolete shortly after they are completed. Success can only be achieved by addressing all these challenges concurrently.

The remainder of this report summarizes the key elements of the refinement process and prefeasibility analysis which the Program designed to address the considerations and challenges outlined in the previous paragraphs.

SPECIFIC ELEMENTS OF THE PROCESS

Agency staff and stakeholders are involved in the process including model selection and selection of modeling assumptions.

Operating Concepts and Rules

Probably the most fundamental problem the Program faces is devising fair and reasonable operating concepts and rules for any new facilities. These rules will largely determine what resources will benefit from any new facilities, whether water supplies will be used to boost drought reliability or average annual water supplies. Concepts and rules for diversion or capture of flows for storage, as well as concepts and rules for release are intimately tied to Program visions for ecosystem restoration and Delta protective standards. The analysis process has been initiated by making some assumptions about concepts for diverting, releasing, and allocating water in the system. The key, though, is to fully explore the interactions of storage and conveyance components with the full range of CALFED goals. Input from the CALFED agencies and stakeholder community as to the appropriate range of operating concepts which will accomplish the goals is important to this process. The Program has been soliciting input on proposed operating concepts over the past six months and is incorporating them in the range of evaluations. These concepts will be refined into more specific operating rules as the process continues.

System Modeling

Any new facilities must fit into California's existing water management system. The Program can explore the effects of new facilities on water supplies, channel flows, reservoir elevations, by means of system modeling tools such as DWRSIM. This is a water accounting model, which estimates the storage and conveyance of water through the system, in accordance with all the concepts and rules devised to protect the Delta, instream flows, and water supplies. California's water management system is very complex, and so must be the model in order to be sufficiently realistic to be credible. As a result, it is a major effort to incorporate new facilities into the model in order to explore CALFED alternatives. Efforts to model the various potential CALFED storage and conveyance components using DWRSIM are underway.

Spreadsheet Post-Processing

Spreadsheet post-processing models are being used to do quicker evaluations to help guide the overall study effort. The spreadsheet models only work with unallocated water in the system. "Unallocated water" does not imply that the water is of no value to any of the beneficial uses including environmental; only that for a given month that there is more water in the system than is required to meet all existing mandated flow and water quality requirements plus water system operational needs. The spreadsheet models allow simulation of new facilities which can store and convey this water without really altering the operations of existing facilities. The Program has been using spreadsheets to evaluate the potential benefits both to the environment and to consumptive uses of adding surface storage components to the existing system under a variety of operating assumptions.

Delta Simulation Modeling

DWRSIM and the spreadsheet models can only estimate in the broadest terms what their effects on conditions in the Delta might be. Detailed Delta modeling is required to evaluate the effects of various proposed conveyance and storage facilities along with proposed operating rules will have on flows, stages, velocities, salinities, and particle transport in the Delta.

The Program has begun the Delta simulation process by picking some representative time periods, without assuming any new facilities outside the Delta. The various proposed Delta conveyance components can then be compared in terms of general effects on tidal amplitudes, flows, and velocities. Later, as the list of Delta conveyance options is narrowed, the Program will integrate the modeling with proposed new facilities upstream and downstream of the Delta.

While advancing modeling of Delta conveyance alternatives, CALFED's modeling staff have also been working to improve the modeling tools themselves. In the fall of last year the U.S. Bureau of Reclamation and the U.S. Geological Survey raised concerns about the accuracy of the current Delta simulation modeling tool used by CALFED, DSM1. New, high quality velocity data has become available over the past several years, which indicated that instantaneous velocities in some channels were much higher than predicted by the model. They expressed concern that this could seriously affect the credibility of the model, which could be a key tool in the eventual selection of a CALFED Delta conveyance alternative. In response, the Program assembled a team of modelers, who have since been working to recalibrate the model, using both new velocity and channel geometry data.

Facilities Inventory

While the modeling efforts can conceptually show how new storage and conveyance might affect stream flows, the Delta, and water supplies, there is a need to also look at specific locations and opportunities for constructing facilities. Every potential dam, pump station, canal, or pipeline has its own particular pros and cons, costs, and impacts. The first step in sorting through all these issues is to develop an inventory of potential storage and conveyance facilities throughout the CALFED problem and solution areas. The Program has developed such an inventory, with about 100 different surface storage, conveyance, and groundwater storage or in-lieu conjunctive use facilities. The draft inventory is available for review and comment.

Having assembled this inventory, the Program will use a reasonable and systematic way to identify those potential projects which might be impractical or have excessive environmental impacts. As indicated earlier, such a process must satisfy regulatory requirements as well as meet CALFED objectives and solution principles. The Program has begun discussions with

CHART 1-A
COMPONENT CONFIGURATIONS A-D

	ALTERNATIVE 1	ALTERNATIVE 2	ALTERNATIVE 3
CONFIGURATION A	Re-Operation	North Delta Improvements 10,000 cfs Hood Intake South Delta Improvements	5,000 cfs Open Channel IF North Delta Improvements South Delta Improvements
CONFIGURATION B	Re-Operation CVP-SWP Improvements	North Delta Improvements 10,000 cfs Hood Intake South Delta Improvements CVP-SWP Improvements 3.0 MAF Upstream Sto. (Sac River Tribs.) 2.0 MAF Aqueduct Sto. 200 TAF In-Delta Sto. 500 TAF Groundwater Sto. (Sac Valley) 500 TAF Groundwater Sto. (San Joaquin Valley)	5,000 cfs Open Channel IF North Delta Improvements South Delta Improvements CVP-SWP Improvements 3.0 MAF Upstream Sto. (Sac River Tribs.) 500 TAF Upstream Sto. (San Joaquin Tribs.) 2.0 MAF Aqueduct Sto. 200 TAF In-Delta Sto. 500 TAF Groundwater Sto. (Sac Valley) 500 TAF Groundwater Sto. (San Joaquin Valley)
CONFIGURATION C	Re-Operation South Delta Improvements CVP-SWP Improvements 3.0 MAF Upstream Sto. (Sac River Tribs.) 1.0 MAF Aqueduct Sto. 500 TAF Groundwater Sto. (Sac Valley) 500 TAF Groundwater Sto. (San Joaquin Valley)	Western 15,000 cfs Isolated South Delta Intake Northern 15,000 cfs Isolated South Delta Intake Eastern 15,000 cfs Isolated South Delta Intake CVP-SWP Improvements	5,000 cfs Pipe IF North Delta Improvements South Delta Improvements
CONFIGURATION D	N/A	10,000 cfs Hood Intake Mokelumne River Floodway (East) East Delta Habitat South Delta Habitat CVP-SWP Improvements 2.0 MAF Aqueduct Sto.	5,000 cfs Pipe IF North Delta Improvements South Delta Improvements CVP-SWP Improvements 3.0 MAF Upstream Sto. (Sac River Tribs.) 2.0 MAF Aqueduct Sto. 200 TAF In-Delta Sto. 500 TAF Upstream Sto. (San Joaquin Tribs.) 500 TAF Groundwater Sto. (Sac Valley) 500 TAF Groundwater Sto. (San Joaquin Valley)

CHART 1-B
COMPONENT CONFIGURATIONS E-H

	ALT. 1	ALTERNATIVE 2	ALTERNATIVE 3
CONFIGURATION E	N/A	Tyler Island Habitat Mokelumne River Floodway (West) East Delta Habitat South Delta Habitat CVP-SWP Improvements 3.0 MAF Upstream Sto. (Sac River Tribs.) 500 TAF Upstream Sto. (San Joaquin Tribs.) 2.0 MAF Aqueduct Sto. 500 TAF Groundwater Sto. (Sac Valley) 500 TAF Groundwater Sto. (San Joaquin Valley)	15,000 cfs Open Channel IF North Delta Improvements CVP-SWP Improvements 3.0 MAF Upstream Sto. (Sac River Tribs.) 500 TAF Upstream Sto. (San Joaquin Tribs.) 2.0 MAF Aqueduct Sto. 200 TAF In-Delta Sto. 500 TAF Groundwater Sto. (Sac Valley) 500 TAF Groundwater Sto. (San Joaquin Valley)
CONFIGURATION F	N/A	N/A	Chain of Lakes North Delta Improvements CVP-SWP Improvements 3.0 MAF Upstream Sto. (Sac River Tribs.) 500 TAF Upstream Sto. (San Joaquin Tribs.) 2.0 MAF Aqueduct Sto. 500 TAF Groundwater Sto. (Sac Valley) 500 TAF Groundwater Sto. (San Joaquin Valley)
CONFIGURATION G	N/A	N/A	5,000 cfs Screened Deep Water Ship Channel and West Delta Tunnel North Delta Improvements CVP-SWP Improvements 3.0 MAF Upstream Sto. (Sac River Tribs.) 500 TAF Upstream Sto. (San Joaquin Tribs.) 2.0 MAF Aqueduct Sto. 200 TAF In-Delta Sto. 500 TAF Groundwater Sto. (Sac Valley) 500 TAF Groundwater Sto. (San Joaquin Valley)
CONFIGURATION H	N/A	N/A	5,000 cfs Open Channel IF Tyler Island Habitat Mokelumne River Floodway (West) East Delta Habitat South Delta Habitat CVP-SWP Improvements 3.0 MAF Upstream Sto. (Sac River Tribs.) 500 TAF Upstream Sto. (San Joaquin Tribs.) 2.0 MAF Aqueduct Sto. 500 TAF Groundwater Sto. (Sac Valley) 500 TAF Groundwater Sto. (San Joaquin Valley)

PHASE II
TECHNICAL EVALUATIONS

IMPACT ANALYSES

The primary technical evaluations during Phase II of the CALFED Bay-Delta Program will be the **impact analyses** for the programmatic EIR/EIS. The impact analyses will examine the differences between the alternatives (including the existing condition and the no-action alternative) at the program level of detail and present the information for decisions on a broad range of alternatives. The impact analyses will provide understanding on how the storage and conveyance components interact with the other components that make up the alternatives, including ecosystem restoration, water quality, levee system integrity, and water use efficiency.

The main purpose of the impact analyses is to compare and contrast the alternatives rather than to optimize sizes, select specific configurations, or select specific sites for any actions within the alternatives. In many cases, the impact analysis will simply provide descriptions of how conditions would be different between the existing condition, the no-action, and the programmatic alternatives. The impact analyses are scheduled for completion by fall 1997.

PREFEASIBILITY STUDIES

The Program will also conduct **prefeasibility studies** for the storage and conveyance, water quality, and ecosystem restoration components; studies for storage and conveyance are underway. These studies will provide more detailed information than that obtained from the impact analyses for the programmatic EIR/EIS. The Program has chosen to conduct impact analyses and prefeasibility studies at the same time rather than conducting them sequentially. However, the prefeasibility studies will continue after the impact analyses are completed. The following paragraphs show some advantages of proceeding now with prefeasibility studies:

> **Provide Support for Impact Analyses** - The prefeasibility studies provide the foundation for the programmatic impact analysis by developing specific information on costs, water supply, flows, water quality, site impacts, and other factors for representative combinations of components. For example, the feasibility of implementing offstream storage to enhance water supply opportunities depends on the specific locations available for development such as topography, geology, environmental concern, proximity to a water supply source, and existing conveyance facilities. By exploring some representative combinations of facilities in terms of specific costs, benefits, and impacts, the prefeasibility evaluations will provide a solid foundation for the programmatic evaluations. These studies help determine the ranges for impact analyses.

Refine Layouts, Sizes, and Other Details - While the impact analyses will evaluate a broad range of facility sizes, the prefeasibility studies provide information for additional sizes within that range. For example, if the range of north of Delta storage is 200 thousand acre-feet to 1 million acre-feet for an alternative, then the impact analysis will examine benefits and adverse impacts for the low and high end of the range, and perhaps an additional anlaysis at the mid-range. The prefeasibility analyses will provide additional detail that may lead to narrowing the range of sizes for the preferred alternative (for example, down to the 500 to 600 thousand acre-feet range).

When alternatives are weighed against program goals and objectives as well as solution principles in selection of a preferred alternative, this higher level of information on all the components, but especially the storage and conveyance components, can assist the stakeholders and decision makers. This additional level of decision support information is the focus of the prefeasibility analysis.

Provide Detailed Costs Not Required for the EIR/EIS - The programmatic EIR/EIS will primarily display benefits and adverse impacts of the alternatives and will include only program level costs for the ends of the range being studied. The prefeasibility studies will provide more detailed cost information to assist the stakeholders and decision makers in their deliberations on the "preferred alternative".

Shorten Time to Implementation - The prefeasibility studies provide early direction for the process of planning, site specific environmental documentation, design, and construction required for project implementation in Phase III. While the studies will not progress so far, before the seletion of the preferred alternative, so as to produce unnecessary analysis, starting the prefeasibility studies before completion of the EIR/EIS will allow the Program to move more efficiently into project implementation.

Operating Parameters

D-005471

CALFED BAY-DELTA PROGRAM

Office Memorandum

Date: February 5, 1997

To: Ad Hoc Meeting Participants

From: Stein Buer SMB

Subject: Suggestions for Operational Criteria, CALFED Bay-Delta Program Modeling

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Attached are four memos documenting operational criteria and concepts for consideration in the CALFED Bay-Delta Program modeling process. As additional suggestions are provided by cooperating agencies and stakeholders they will be made available for review and comment. The attached memos include:

- EPA. January 1997. EPA Guidance to Storage and Conveyance Modelers
- The Bay Institute. December 23, 1996. Operational Criteria for CALFED Modeling
- David Fullerton. December 12, 1996. Ideas on Conveyance and Storage Analysis by CALFED
- Environmental Defense Fund. January 27, 1997. CALFED Modeling of Proposed Storage and Conveyance Facilities

These memos do not reflect established CALFED policies or modeling assumptions, but will be considered along with other input, in formulating operational criteria for a series of system and Bay-Delta evaluations.

Jan. 1997

MEMORANDUM

SUBJECT: EPA Guidance to Storage and Conveyance modelers

FROM: Bay/Delta Team

TO: Stein Buer, DWR

On December 20, EPA staff met with representatives of the environmental community to discuss common concerns with the identification of 'environmental' water in the CalFed modeling efforts. This memo summarizes some of that discussion.

In the present absence of consensus on a CalFed methodology for determining the 'time value of water,' modeling could reasonably proceed using several input constraints representing 'environmental' water. Model runs of alternative storage and conveyance components with these input constraints would provide information helpful in the refinement process. However, neither the input constraints nor the output results can be expected to reflect the water quality standards and other parameters that would be appropriate for the selected alternative.

Input constraints.

1. A version of the CVPIA's AFRP actions, modified to suit the scope of CalFed's alternatives, would better represent flow needs for anadromous fish than any of the goals heretofore used. With very little work most of the CVPIA AFRP actions about flows, both upstream and downstream, could be entered as model constraints. Because these actions were developed only to address impacts of the present system and were designed to limit impacts to waterusers under the present system, the actions will need to be reviewed with the people who developed them in order to make them more useful for CalFed's purposes.

2. For resident species an improvement in the estuarine water quality standards (X2) would be an excellent approximation of environmental water needs (at least at the level of detail accommodated by the modeling tools). Two changes of the current X2 requirements could be used:

a. Improvements in the baseline level of protection by moving the maximum X2 location from Collinsville to Chipps Island.

b. Improvements in the Level of Protection used to set the various sliding scales that identify the number of days required at each site in each month. Several levels of protection would provide the greatest amount of information; possibly an early 1960s level, a pre-export level (1950s) and a pre-Shasta/Friant level (1940s).

Of course, these two X2 changes are not mutually exclusive and a combination would represent an outer bound on the amount of environmental water that could be needed by resident species.

3. In addition, it may be possible to produce, within a relatively short time period, guidance to CalFed on constraints relating to three other environmental concerns:

a. Rewrite the percent diverted requirements so that they would apply to all three alternatives in a meaningful way. In this rewrite the allowable percent exported would change with inflow so that a level of protection could be targeted in every year type.

b. Protection of some peak flood flows that provide important ecological values and which might be curtailed by new storage and conveyance structures. These would likely be similar to the channel maintenance flows that have been discussed for the Trinity River. This process might also identify flow levels needed for some ecological restoration actions of CalFed to succeed, such as flows consistent with the meandering of riverbeds within a river plain. Identification of these flows would need to identify their magnitude, duration and frequency.

c. Weight water values in extremely dry years differently than in most years. Correspondence with the Storage and Conveyance team has suggested that in some years water prices could reach $2000/acre-foot, at which times alternative water sources such as desalinization may be appropriate for those uses that can use such sources. Contrariwise, these years are often naturally the most stressful to aquatic resources and when they are least able to accommodate the various impacts of diversion.

EPA could facilitate development of guidance on these points among regulatory agencies and environmental interests.

Modeling outputs

Under the constraints described above the operations of the various alternatives could be evaluated by examining a number of parameters (in addition to delivery volumes). Specific outputs that should be included in the outputs include:

1. For each of the alternatives, compare resulting hydrographs (the tributaries, delta inflows and delta outflows) with the hydrographs associated with unimpaired, existing conditions, future conditions without the project and recent history.

2. Salinity in the lower San Joaquin River during striped

bass spawning season (April-June).

3. QWEST values during salmon outmigration period (October-June).

4. Comparisons of the above descriptors of hydrograph, salinity and QWEST during the latter halves of the 1928-1934 and 1987-1992 droughts.

5. San Pablo Bay mean salinities and frequencies of occurrence of X2 in San Pablo Bay during times of sensitivity of starry flounder, Crangon, and emergent vegetation.

6. Richardson Bay mean salinities during herring spawning season (October-January).

7. Frequency of flows associated with stratification of South San Francisco Bay.

Interpretation

These inputs and outputs would address many of the water quality and ecosystem issues that CalFed may affect. We believe that model runs that reflect these concerns will be a useful step in identifying the costs and benefits to the environment of various formulations of storage and conveyance facilities. However, it would be inappropriate to consider this either a complete list of environmental concerns or a list of environmental goals for CalFed's alternatives. Because comparison of the alternatives includes achievement of project goals as well as estimating project impacts, a broad suite of environmental effects will need to be modeled.

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The Bay Institute of San Francisco

*** MEMORANDUM ***

December 23, 1996

TO: Stein Buer

FR: Gary Bobker

RE: Operational criteria for CALFED modeling

Since our meeting with you on November 27, Peter Vorster and I have discussed a number of issues internally and with other organizations regarding the operational criteria for modeling the CALFED storage and conveyance alternatives. What follows is a summary of our preliminary thinking on the environmental criteria; some of it applies to the spreadsheet modeling, some to the subsequent DWRSIM runs. Peter will be sending you a memorandum concerning additional modeling issues under separate cover.

Environmental flow improvements

A more comprehensive set of operational criteria for environmental flow improvements needs to be incorporated into the modeling, including:

1. Anadramous fish doubling flows -- All alternatives modeled should assume that flow objectives for tributary and Delta habitat protection contained in the CVPIA Anadramous Fish Restoration Program are being met.

2. Flows to increase protection of existing estuarine habitat -- Operating to meet a year-round Delta outflow objective of 7,000 cfs fails to address the most critical ecosystem needs. Improvements in the occurence of low salinity shallow water habitat in Suisun and San Pablo Bays and the Delta and increased Delta outflows for transport of aquatic organisms are most critical in the February - June peak spawning and migration period (we are assuming for modeling purposes that most anadramous fish flow needs in the July - January period should be covered by attainment of the AFRP doubling flows, but that all non-anadramous fish and foodweb needs are <u>not</u> completely met by attainment of the AFRP doubling flows in the February - June period). The modeling runs should therefore assume seasonal Delta outflow improvements; most importantly, we would recommend

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changing the February - June requirements for location of the X2 salinity isohaline to reflect earlier levels of development (i.e., 1950 and 1960) than currently required (1971.5). In any case, specific flow/salinity objectives to restore natural hydrological patterns for estuarine habitat and transport of aquatic organisms need to be developed as part of the CALFED Ecosystem Restoration Program Plan and incorporated into the modeling runs.

3. Flows to support restoration of new estuarine habitat -- In addition to restoring water quality conditions and natural hydrological patterns for existing estuary and tributary habitat and for transport of aquatic organisms, CALFED is also proposing to restore a number of key physical habitats throughout the estuary. Therefore, guidance in the CALFED ERPP on flow regimes that will ensure the desired amount and duration of inundation of restored meander zones and floodplain wetlands, inflows to restored freshwater tidal wetlands, etc, will be necessary for modeling the alternatives.

4. Flood flows -- Restoration of flood flows to maintain channel integrity and natural river processes may require the occurrence of multiple peak flow events of or in excess of 60,000 cfs. In addition, peak springtime flows in excess of 100,000 cfs may be necessary to maintain stratification in the South Bay. We believe that this criterion merits further consideration by the CALFED ERPP staff. Specific targets for restoration of flood flow variability are also being developed jointly by The Bay Institute and the Environmental Defense Fund for recommendation in 1997.

5. Export criteria -- We understand that CALFED intends to consider both use of the current export/inflow ratios and dropping the e/i ratios when modeling the isolated Delta conveyance alternative. However, since the current e/i ratios have no biological basis, it seems to us to be a high priority for the CALFED ERPP staff to develop one or more options for more protective export criteria, whether linked to inflows, outflows, entrainment, etc., to be used in addition to a simple with/without scenario when modeling all the alternatives. David Fullerton and I worked on some ideas for alternative export criteria in 1994 which might help stimulate consideration of this issue by CALFED.

<u>Environmental constraints</u>

The environmental flow improvements discussed above are supplemental to existing operational criteria. Even with these improvements assumed in the CALFED modeling runs, however, additional constraints on operation will need to be developed as part of the EIR/EIS process depending on the impacts of the different CALFED alternatives on a number of key environmental variables. To

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aid in the impact analysis, the CALFED modeling runs should evaluate the following impacts of the storage and conveyance alternatives:

1. Deviation from location of the X2 salinity isohaline (i.e., actual location downstream of the current compliance stations) under the existing operational baseline.

2. Deviation from actual average mean salinities in the Delta and Suisun, San Pablo and San Francisco Bays under the existing operational baseline.

3. Deviation from unimpaired flows, historic flows and the current operational baseline for Delta outflow and tributary flow.

4. Deviation from net positive flow on lower San Joaquin River.

5. Deviation from salinity levels (land-derived salts) on the lower San Joaquin River under the existing operational baseline.

cc: Peter Vorster, Elise Holland, TBI
David Fullerton, NHI
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Terry Mills, Frank Wernette, CDFG

MEMO

To: Stein Buer
From: David Fullerton
Subject: Ideas on conveyance and storage analysis by CALFED
Date: December 12, 1996

This memo is very rough, but should give you the flavor of my thoughts. Most of my comments have to do with the need to look at a wide variety of possible operational assumptions.

1. The analysis should allow some assessment of the system flexibility associated with the physical alternative. There are many future uncertainties. We probably cannot and should not lock in rigid operational rules ahead of time, but will need to operate both in real time and adaptively. Similarly, we presumably want to know how well the final infrastructure will allow market transfers in the future. Two alternatives could get the same scores for environmental flow enhancements and supply enhancements under one operational scenario, but be radically different in their performance under a wide variety of operational scenarios (different environmental flow regimes, different future demands, the development of markets, Delta hydrodynamics etc. that are unexpected). CALFED should give major bonus points to solutions which score well under a wide variety of operational and demand assumptions. The best solution will be one which is adaptable, not one which scores the highest for single selected operational scenario.

To put this more in modelling language, I am arguing for an analysis that (1) looks at various market scenarios and (2) performs sensitivity analysis in which operational rules (including standards), assumed Delta hydrodynamics, demand patterns, etc. are varied across the range of the possible.

2. The export/inflow standard is one example of a standard which cannot be considered definitive. There is no scientific basis for the standard. With better information, we may come up with a standard which is quite different. Look at the San Joaquin April/May Vernalis flow/ export standard as an example. We set a flow standard and an export ratio standard, but all acknowledge that these standards may not be well matched to environmental needs. Maybe flow is the dominant factor. Maybe it is exports. Maybe it is the ratio of flow to export. Maybe it is the difference between flow and export. Each variation has operational and supply implications. A good physical solution would be one that could accommodate each of those possible standards. A solution that only worked for one variation would be very brittle and very risky. The same is true on a larger scale within the Delta. Thus, we need to look at QWest standards, standards where exports are a function of individual tributary inflows, standards emphasizing flows, standards emphasizing control of exports, etc.

3. Any isolated facility alternative should be tied to Delta outflow standards -- year round --

otherwise the facility could conceivably draw down Delta outflows far more than is possible today. Internal Delta salinity standards may provide this kind of protection, de facto, but I am not sure that the combination of X2 and salinity standards for farming provide total coverage. Also, as a matter of policy, the outflow should have its own standard, since farmers could conceivably be bought out, making the ag salinity standards obsolete.

4. When looking at environmental storage (or user storage for that matter), different rule curves should be studied, reflecting different theories of environmental protection. If dry years are 20 times more damaging than normal years, then it would be prudent to husband storage for use during the driest years. This will reduce average managed environmental outflow, but could increase environmental benefits. South of Delta environmental storage should be explicitly managed to reduce exports during critical periods (again, with the choice between frequent reductions in exports with lower average reserves, versus saving storage to suppress exports very much in the driest years). A proxy for explicit management of environmental storage south of the Delta might be tightened export standards. Such standards would force export operators to act as if the environment controlled its own storage.

5. The rules curves chosen by the modelers will probably have a major impact on the amount of storage determined to be optimal. In general, the existing model runs simply deplete storage whenever there is unmet demand (whether environmental or user) that can be served by storage. This is unrealistic. In practice, some amount of hedging goes on. In general, the more conservative the rule curve (i.e., the more biased it is toward maximizing dry year supplies instead of maximizing average supplies), the greater the benefits of increased storage (when you empty your reservoir every year or two, you are incapable of ever filling a large space). All things being equal, this means that the storages chosen using the current rule curves represent a lower bound on the appropriate level of storage. This is not to say that we need very large amounts of storage, only that the analysis should look at a spectrum of reasonable rule curves. As I note below, better coordination between various types of storage will tend to depress optimal storage levels.

6. I wonder whether it is misleading to simply present results in terms of acre-feet accomplishments during average years and the dry year sequence. Dry year water is worth thousands of dollars per acre-foot to urban customers. Dry year water is probably worth far more to fish than normal year water, gallon for gallon. The optimum solution will probably be one which balances our desire to protect against major losses in dry years, while still providing some enhanced benefits during normal years. I recommend creating a weighted index in which dry year performance is given a greater weight than wet year performance. We may still argue over the relative weights to assign, but it will at least make clear that we are arguing over the value of water, not volume. As noted above, the high values attributable to dry year water will tend to favor solutions which are fairly conservative and which have greater amounts of storage.

7. Various types of storage need to be used in a coordinated fashion of they are to be used

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most efficiently. I envision a storage cascade in which: (1) groundwater storage has the highest priority for filling (because it is slow to fill), then off stream storage, then Delta island storage, then onstream storage; and (2) storage is depleted in lower priority storage sites to fill higher priority storage sites whenever capacity is available. Thus, we would not treat south of Delta surface and groundwater storage sites as unlinked storage sites. Rather, the offstream storage would feed water into the ground whenever there was free capacity. Similarly, Delta storage would feed water into groundwater and south of Delta offstream storage when capacity was available. Storage from onstream reservoirs would feed into all other storage sites when available. Obviously this is an oversimplification. You would never want to draw down onstream storage too much, and you would need to consider the cost of retrieval from groundwater, but you get the idea. Using the cascade concept, we use each type of storage facility at the most appropriate temporal frequency -- we don't use Delta islands for carryover storage or off stream sites for long-term storage. Rule curves that would allow better coordination of storage would actually increase the amount of benefits possible from any given level of storage. I don't know if this kind of analysis can be done using the spreadsheet approach. I think, though, that it would show that using storage in a coordinated fashion provides major benefits and allows us to get by with less storage.

8. Re: the Sacramento pulse flow standard. It is not at all clear to me that 60 kcfs is adequate protection for the Delta or the Bay (of course, there will also be contributions to outflow from SJR and eastside flows) or that only one pulse per year is adequate. Ultimately, I think that our pulse flow standards may need to be statistical in nature, based upon some sort of biological criteria. For example, say we think we need one pulse over 300 kcfs on average every 5 years, 100 kcfs every year, and 50 kcfs three times a year. We could then do a 10 year running statistical analysis of past flow patterns. If our statistical requirements are in good shape, (we are in a wet cycle), then diversion and storage restrictions might be reduced. If we are falling below our desired statistical pattern, then outflow gets a higher priority until we get back to the curve. In this way we get the protection we need, without having to protect every single pulse.

9. A related issue: one good way to protect pulses for the Bay would be to create a new X2 control point for purposes of analysis which would be triggered the way Roe Island is triggered now. This would actually be a way to protect pulses without having to go through the statistical analysis mentioned just above. Flow needed to push X2 downstream rises exponentially as X2 gets smaller. Simply increasing the number of X2 days at Roe Island doesn't give any assurances that the really high flows will be there. Only moving the X2 compliance point downstream will do that. Of course, once the control point is very far downstream, then the flows needed to activate that point will be very large. Such flows cannot be effectively controlled with current facilities in most instances. However, I am concerned about the scenario in which we get a big storm after a multiyear drought. Without a downstream X2 control point, most of the runoff will be held in onstream storage. This could be devastating to the environment.

10. I agree with assuming that the state and federal export facilities are coordinated. We are

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not going to go all the way through the CALFED process, and then have uncoordinated state and federal operations.

11. I am interested in looking at possible infrastructure requirements for maximizing conjunctive use. I am not talking about new Delta diversion capacity. My concern is more with the capacity of distribution systems south of the Delta. Maximizing groundwater storage will probably require big distribution systems (because to get reasonable deposition rates, we need many sites). My question is, "is conjunctive use limited by the state and federal canals or by the distribution network?" If the answer is distribution, then we can suggest the inclusion of new distribution as a CALFED action in order to maximize groundwater storage.

12. I have two concerns with the spreadsheet model. First, it is a perturbation model -- it asks "what if" questions based upon a baseline run. As we move further and further away from the baseline, the validity of the model becomes questionable. Second, the model does not allow reoperation of existing reservoirs. Of course, promising courses of action can be followed up with more detailed DWRSIM runs. We run two main risks in relying upon the spreadsheet model: (1) CALFED will reject a good alternative because its advantages could not be captured by the spreadsheet model -- and therefore never do the follow up DWRSIM run which would show the benefits; and (2) a good alternative will be overlooked because no one bothers to look at it. As long as we use a wide variety of DWRSIM baselines which cover the span of the possible, then the risk of rejecting a good alternative should be reduced. To make sure we get adequate coverage, however, we will need to distribute the model and encourage the stakeholders to try out their own ideas.

13. Some runs need to be done which assume that CALFED has taken actions to allow the flow requirements for navigation on the upper Sacramento River to be dropped. If we can can gain large water mangement benefits for the cost of extending a few pipes, then this will make the job of CALFED a lot easier.

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EDF
ENVIRONMENTAL
DEFENSE FUND

California Office
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Oakland, CA 94618
(510) 658-8008
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MEMORANDUM

To: Stein Buer, CALFED

From: Spreck Rosekrans

Date: January 27, 1997

Subject: CALFED Modeling of Proposed Storage and Conveyance Facilities

Baseline

Baseline operations under the CALFED alternatives should be consistent with the best guess of a "No Action" scenario, or how existing facilities would be operated if no CALFED recommendation were to be adopted. The core of these projected operations ought to include the 1995 WQCP, and implementations of the CVPIA and proposition 204 (without federal matching funds at this point). The CVPIA elements ought to include use of the Act's water management tools, including the dedicated yield and acquired water in Sections 3406(b)(2) and (b)(3).

Alternatives

EDF does support study of an "environmental" reservoir (or a part of a reservoir dedicated to environmental needs), which could be used, if located south-of-delta, to reduce exports on a real time basis by delivering its water to users as an alternative supply, or if located north-of delta, to release water for additional outflow. EDF's support of such a reservoir would depend on a consideration of all of its potential environmental impacts and the degree to which it furthers the restoration of the natural hydrograph, hydraulic regime, and ecosystem structure and function.

Analysis of Environmental Performance

Performance measures ought to include estimates of habitat structure, habitat function, and fish survival. For preliminary studies, it may not be important whether all environmental performance criteria be incorporated as constraints which drive the model or merely reported as model output. Eventually, however, many of the environmental criteria should be considered constraints.

Habitat measures (related to flow) should include both X2 location and the timing and volumes of instream flows. X2 levels studied ought to include a level of development at least as far back as 1960 as well as, in some years, compliance locations downstream of Roe Island. Instream flow criteria should be at least as great as those specified by the AFRP.

Survival estimates should include projections of entrainment at export pumps or other diversions. Leading experts should be asked to assign probabilities of entrainment based on categories which include the following: species, life stage, time of year, percent of relevant flow diverted, location of diversion, screening efficiency. These survival estimates should initially be reported and eventually be used to "drive" the models.

How to Model Alternative Storage and Conveyance Facilities

Any combination of facilities can be operated in a variety of ways. It is therefore only reasonable that any particular combination of facilities be modeled, within reasonable limits, according to a matrix of scenarios which manage three principal components: the ecosystem, water supply and flood control. The optimal alternative may not be the one which performs best under a single set of assumptions, but performs well under many different operational scenarios.

- The current status of ecological science does not allow either agencies or stakeholders to accept without condition many combinations of facilities and operating criteria. Any given set of facilities ought to be modeled with multiple levels of the best available estimates of varying levels of environmental protection.
- Decision-makers will choose policies which seek a balance between operations which achieve greatest long-term average water supplies for agriculture and urban interests and those which assure some level of supplies during a long-term drought. Unless there is consensus among parties as to how that balance will be determined, alternatives ought to be measured according to how well they meet a variety of policies.
- Similarly, flood control policies or even climate may change. The modeling of alternatives ought to take these possibilities into consideration.

Modeling should reflect institutional changes as well as physical changes. For example, how would ecological, water supply and flood control be affected if CVP water users were allowed to use available surplus SWP pumping capacity within the existing facilities. The current configuration incorporates the wheeling restriction as a de facto environmental constraint. CALFED should be both careful and very clear as to exactly what assumptions of this kind are or are not incorporated.

Possibilities for combinations of agencies and districts to control the distribution of water are endless. While modeling studies may not be able to consider all possible configurations, it is probably not acceptable to assume generally that all facilities operate as a joint project (as was the case in the DWRSIM modeling that led to the Bay/Delta Accord)

Modeling Issues

It is common for a base modeling simulation to be produced by far greater effort and undergo substantially more scrutiny than alternative simulations. The result is that a base simulation may be more "optimized" (for one or more objectives) than alternatives. There is no simple answer to this problem, but it should be explicitly acknowledged and an attempt should be made to resolve whether alternative results may be skewed in comparison to the base simulation.

The models will use rule curves to govern operations. Will these rules actually govern operations in the real world? CALFED analysis should include a discussion of what rules within any particular study would be subject to change.

The use of both (mega) spreadsheets and DWRSIM is probably a good idea. Of course, the two models should be calibrated to each other for the base simulation. The reported inability of the spreadsheet model to operate reservoirs, if true, must be considered a limitation.

Richard Denton's G-model should be used as the default for interior Delta flow/salinity relationships, unless a better method is developed.

Monthly decisions within DWRSIM and the spreadsheets should rely on a forecast that would be available at the time and not on perfect foresight. If a model iterates "to get a year right", these iterations should not be based on future precipitation.

System Modeling

State of California — DEPARTMENT OF WATER RESOURCES — The Resources Agency

OFFICE MEMO

TO: Stein Buer, CALFED	DATE: March 7, 1997
FROM: Sushil Arora	SUBJECT: System Modeling Studies of CALFED Alternatives

Per your January 22, 1997 request, attached is a status report on system modeling conducted with DWRSIM for Phase II of CALFED's Storage and Conveyance Refinement Process. Thirteen preliminary studies have been completed or are currently in progress. This preliminary work considers combinations of the following alternative components: dual Delta conveyance, north of Delta offstream surface storage, and south of Delta off-aqueduct surface storage.

The attached report includes:

- a brief description of the DWRSIM model

- a matrix of the thirteen studies with key assumptions

- a sensitivity analysis of dual Delta conveyance operating criteria

- some preliminary water supply benefits

No preliminary results are reported for studies that include new surface storage. The preliminary nature of these studies renders any conclusions drawn from them tentative. Further refinement in facility operating criteria will continue.

Results from completed DWRSIM model studies can be accessed through the DWR Modeling Support Branch web page; the URL for this web page is *http://wwwhydro.water.ca.gov/calfed.html*. If you have further questions, please call me at 916-653-7921 or Paul Hutton and 916-653-5666.

Attachment

cc: Kathlin Johnson
George Barnes
Mark Cowin

DWR 100a (Est. 4/80) ☐ OVER

CALFED'S STORAGE AND CONVEYANCE REFINEMENT PROCESS: A STATUS REPORT ON SYSTEM MODELING WITH DWRSIM

SUMMARY

System modeling will provide the CALFED storage and conveyance refinement process with information regarding potential water supply benefits for environmental enhancement and urban and agricultural uses. Preliminary system modeling was conducted with the DWRSIM model. This preliminary work considered combinations of the following alternative components: dual Delta conveyance, north of Delta off-stream surface storage and south of Delta off-aqueduct surface storage. Analysis of DWR's ISDP facilities (south Delta improvements) and modified operating rules that maximize SWP wheeling of CVP water was also conducted. In all, 13 preliminary DWRSIM runs were completed or are in progress as outlined in Appendix I.

There is a great deal of variability in how alternative components might be operated. Benchmark assumptions and component operating assumptions are provided in Appendices II and III, respectively. Such variability renders any conclusions drawn from the DWRSIM study results presented herein tentative. A sensitivity analysis of dual conveyance facility operational criteria is presented to illustrate this point. Finally, the following tentative observations are made with respect to completed studies:

1. "Maximized" SWP wheeling of CVP water appears to provide only small water supply benefits with benchmark Delta facilities and operating rules. Long-term average benefits are enhanced with south Delta improvements in place.

2. Water supply benefits are provided by dual Delta conveyance facilities when isolated conveyance is excluded from WQCP export restrictions and Delta cross channel gates are strategically operated. Short of these measures, the facilities may result in water supply costs. Water supply benefits do not appear to be sensitive to increases in isolated facility size when additional storage opportunites are not provided. Drinking water quality benefits, as measured by the quantity of water conveyed through the isolated facility, are substantial but show diminishing returns with increases in facility size.

MODEL DESCRIPTION

DWRSIM is a generalized computer simulation model designed to simulate the operation of the Central Valley Project (CVP) and the State Water Project (SWP) system of reservoirs and conveyance facilities. The model accounts for system operational objectives, physical constraints, legal requirements, and institutional agreements. These parameters include requirements for flood control storage, instream flows for fish and navigation, allocation of storage among system reservoirs, hydropower production, pumping plant capacities and limitations, the Coordinated Operating Agreement (COA), and required minimum Delta operations to meet water quality and Delta outflow objectives.

Existing & Proposed Facilities

Key system reservoirs and conveyance facilities are schematically represented in DWRSIM. The Sacramento Valley basin network includes the Sacramento River upstream to Lake Shasta, the CVP's Clair Engle/Whiskeytown complex, the Feather River upstream to Lake Oroville, and the American River upstream to Folsom Lake. The San Joaquin basin network includes the Stanislaus River upstream to New Melones Reservoir, the Tuolumne River upstream to Hetch Hetchy and Cherry/Eleanor Reservoirs, the Merced River upstream to Lake McClure, the Chowchilla and Fresno Rivers upstream to Eastman and Hensley Lakes, respectively, and the San Joaquin River upstream to Millerton Lake. The Delta network includes the Sacramento and San Joaquin Rivers, eastside streams and a flow path through the Delta cross channel/Georgiana Slough. South of the Delta, the following facilities are modeled: the Delta Mendota Canal, the South Bay Aqueduct (including Lake Del Valle), the California Aqueduct (including the CVP-SWP Joint Reach, San Luis Reservoir, Pyramid and Castaic Lakes, and Silverwood and Perris Lakes), and the Coastal Aqueduct.

Several CALFED reservoir and conveyance facilities are also schematically represented in DWRSIM. These facilities include a north of Delta offstream surface storage facility, a north of Delta groundwater storage facility, dual Delta transfer facilities, an in-Delta storage facility, a south of Delta off-aqueduct surface storage facility and a south of Delta groundwater storage facility.

Hydrology

The DWRSIM operations studies conducted for CALFED's storage and conveyance refinement process use a historical 73-year hydrologic sequence of flows from water years 1922 through 1994 as input. The hydrologic sequence is adjusted to reflect the effect of estimated 1995 level land use patterns. This adjustment is developed using two other models: the Consumptive Use model and the Depletion Analysis model. The hydrology is also modified to account for current operations of local upstream reservoirs. San Joaquin River basin hydrology was adapted from the USBR's SANJASM model.

Water Quality

DWRSIM employs a variety of relationships to define water quality requirements in the Delta and in the San Joaquin River. The Kimmerer-Monismith equation is used to calculate outflow requirements for "X2" objectives. Contra Costa Water District's "G" model is used to calculate outflow requirements for water quality objectives at Chipps Island, Collinsville, Antioch, Emmaton, Jersey Point and Rock Slough. Finally, a flow-salinity relationship upstream of the Stanislaus River is used in combination with a simple salt balance to calculate required water quality releases for the Vernalis salinity objective.

Project Deliveries

DWRSIM simulation results estimate how the entire system would perform when trying to meet project demands, assuming recurrence of the historical 73-year sequence of hydrology at the 1995 level of development. The CVP and SWP export demand south of the Delta is based on a future

2020 level of development. The model's south of the Delta delivery logic uses (i) runoff forecast information and uncertainty rather than perfect foresight, (ii) a delivery versus carryover risk curve and (iii) a standardized rule to estimate the total water available for delivery and carryover storage. The logic updates delivery levels monthly from January 1 through May 1 as water supply parameters become more certain.

Limitations

DWRSIM has a number of limitations which require that caution be exercised when analyzing or interpreting model results. Many of these limitations are due to lack of information or objective criteria, and would be limitations of any similar model. Some of the more important limitations are discussed below:

1. DWRSIM operates on a monthly time step. Therefore assumptions must be made to model any standard that is not formulated on a monthly basis. Additionally, peak storm flows, which are usually considerably higher than monthly average flows, cannot be modeled.

2. The ESA limitations on Delta export pumping based on actual "fish take" cannot be modeled.

3. The CVPIA mandates that 800 TAF of CVP yield be allocated for environmental purposes. The USBR has not yet fully established criteria on how this obligation will change CVP operations, or how much additional Delta inflow or outflow this mandate will provide (some instream flow prescriptions have been defined for the DWRSIM simulations). Until such criteria are established, interpretation of modeling results are subject to the uncertainty of the CVPIA allocation.

4. The effect of the ESA requirements or other proposed standards on the sharing formula in the COA is unknown. This sharing will affect relative reservoir levels and available water for delivery between the CVP and SWP.

5. DWRSIM primarily simulates the CVP and SWP system of reservoirs and conveyance facilities. This system is, therefore, used as a surrogate to estimate water supply impacts throughout the Central Valley. Actual responsibility to meet Bay-Delta standards might be allocated among other water users as well.

6. The Depletion Analysis model accounts for use of groundwater, but groundwater itself is not physically modeled.

7. DWRSIM is not capable of analyzing the water supply impacts of water quality objectives for the interior stations in the southern Delta because of a lack of adequate understanding of relationships between the San Joaquin River flow and southern Delta water quality.

DWRSIM STUDIES MATRIX & ASSUMPTIONS

The purpose of the CALFED's Phase II storage and conveyance refinement process is to develop information regarding potential water supply benefits for environmental enhancement and urban and agricultural uses. Through the refinement process, CALFED will evaluate various facility components and combinations of these components. DWRSIM analyses have thus far been limited to dual Delta transfer facilities and surface storage north and south of the Delta. A matrix of DWRSIM studies completed or currently in progress is presented in Appendix I. As noted in Appendix I, some of these study results can be accessed through the DWR Modeling Support Branch web page at the URL *http://wwwhydro.water.ca.gov/ calfed.html.*

There is considerable variability in the criteria that might be selected for operating the system to achieve environmental, water quality and water supply goals. For the most part, it was assumed that the system would be operated according to existing rules, including the SWRCB's May 1995 Water Quality Control Plan. Benchmark assumptions defined for the DWRSIM studies matrix are provided in Appendix II. Additional assumptions were required to operate the proposed additional storage and conveyance components. These assumptions are set forth in Appendix III.

OPERATIONAL CRITERIA VARIABILITY: AN ILLUSTRATION

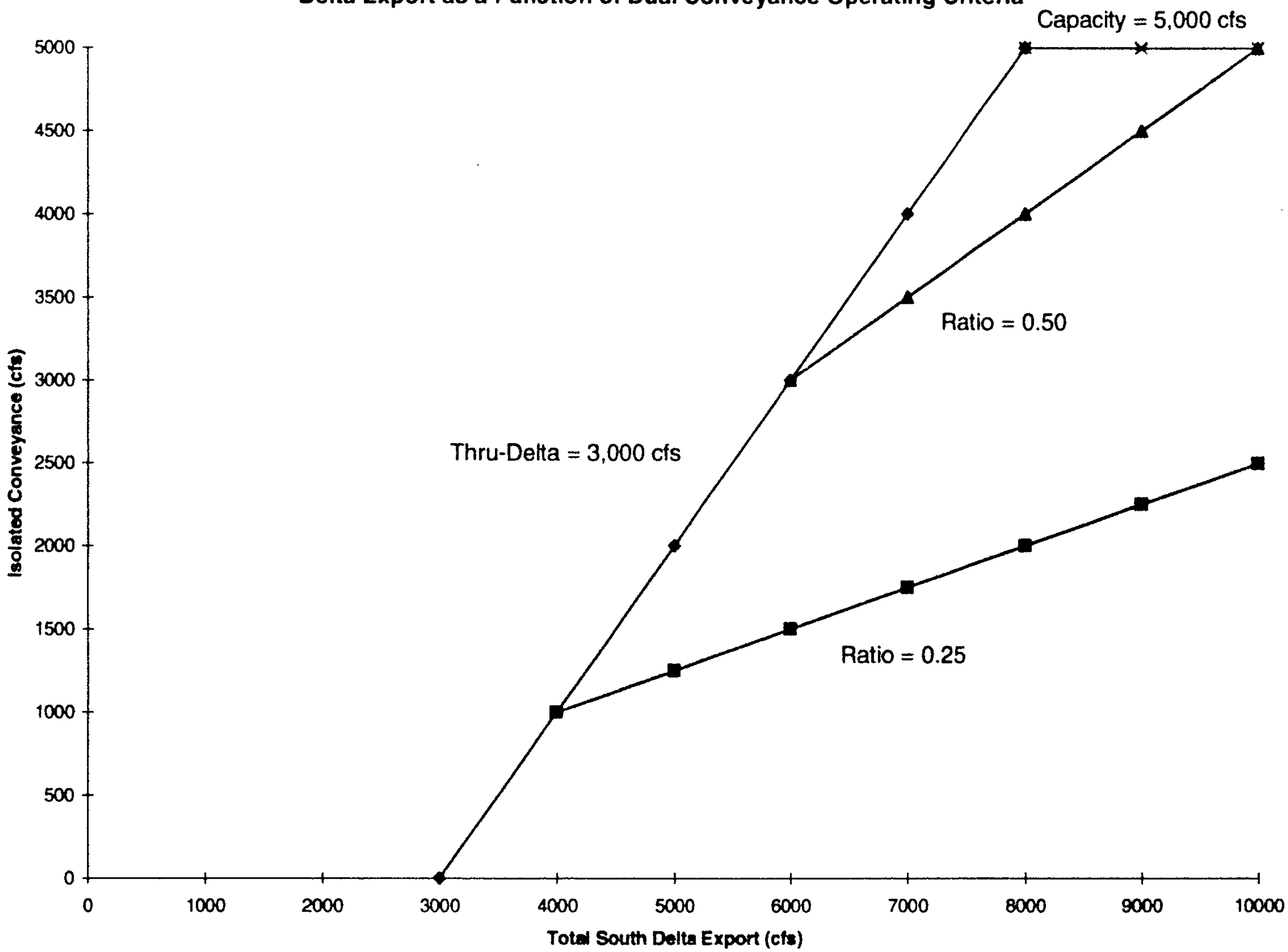
As stated in the previous paragraph, there is a great deal of variability in how alternative systems might be operated. There are many ways to integrate the CALFED storage and conveyance components into the overall system operations. There are many ways to share benefits between environmental, agricultural and urban needs. **Such variability renders any conclusions drawn from these DWRSIM operations study results very preliminary.** To illustrate the influence of operational criteria on DWRSIM study results, a sensitivity analysis of dual conveyance facility criteria is presented.

Dual Facility Operating Objective & Parameters

The dual transfer facility is operated to maximize drinking water quality benefits by allowing for maximum isolated conveyance subject to a number of operating constraints. As outlined in Appendix III, isolated conveyance is governed by (i) a minimum thru-Delta conveyance, (ii) a maximum isolated conveyance ratio, (iii) a physical design capacity limit, (iv) Project service restrictions and (v) export ratio restrictions. Selection of different operating criteria will, naturally, result in different isolated conveyance.

To illustrate how the dual transfer facility is governed by operating criteria, Figure 1 shows the relationship between isolated conveyance and total south Delta exports for a 5,000 cfs facility that (i) does not operate unless a minimum thru-Delta conveyance of 3,000 cfs exists, (ii) serves both the SWP and CVP, and (iii) does not operate under WQCP export restrictions. The figure shows that at the x-intercept, no isolated flow is permitted until total south Delta exports exceed 3,000 cfs. The figure also shows that isolated flows never exceed the design capacity of 5,000 cfs. Within these two bounds, the relationship is defined by the ratio constraint. In this example, the ratio constraint controls operation only if it is set at less than 0.62 (the operating point where isolated flow is 5,000 cfs and total south Delta export is 8,000 cfs). If the ratio constraint is set at 0.5, the thru-Delta conveyance constraint controls up to a total south Delta export of 6,000 cfs, after which the ratio constraint controls up to a total south Delta export of 10,000 cfs. At higher exports, the 5,000 cfs design capacity controls operation.

Figure 1
Relationship Between Isolated Conveyance and Total South Delta Export as a Function of Dual Conveyance Operating Criteria



Initial Sensitivity Analysis

Sixteen DWRSIM runs were conducted to gain some insight into how the system responds to different dual transfer facility operations. The sensitivity analysis considered different physical capacities, different minimum thru-Delta conveyance constraints, different Delta cross channel gate operations, and different export ratio restrictions. The primary conclusions from this initial sensitivity analysis were that (i) cross channel gate operations have significant water supply impacts and (ii) inclusion of isolated conveyance flows in the definition of Delta "inflow" and "export" results in the facility providing no water supply benefits (and may result in water supply costs). Further details on the initial sensitivity analysis are provided in Appendix IV.

Further Sensitivity Analysis

Based on the conclusions derived from the initial sensitivity analysis, baseline operational criteria for dual conveyance facilities were defined as follows for the current matrix of studies:

1. Delta cross channel gates are closed September through November (September through December for larger facilities) to reduce water requirements associated with the Rio Vista flow standard.

2. Isolated Facility flow is excluded from all export restrictions.

3. Minimum thru-Delta conveyance is 3,000 cfs every month.

4. The maximum ratio of isolated conveyance to total south Delta export is 0.7 every month.

Further sensitivity was explored with respect to design capacity, maximum ratio and minimum thru-Delta conveyance. Design capacities of 5,000 cfs, 10,000 cfs and 15,000 cfs were explored. Complete relaxation of the maximum ratio (ratio = 1.0) was explored. Finally, a relaxation of the minimum thru-Delta conveyance constraint from 3,000 cfs to 1,000 cfs during January through March was explored. This relaxation period was selected because it falls outside the irrigation season and the Rio Vista flow standard period. Furthermore, during this period, Delta waters tend to have high concentrations of total organic carbon from local drainage activities. Total organic carbon is a constituent of concern for drinking water quality.

Table 1 below shows the results of this sensitivity. Note that water supply benefits, as compared with benchmark conditions with south Delta improvements in place (Study 472B) are insensitive to changes in these parameters. However, drinking water quality benefits (as measured by the quantity of water delivered through the Isolated Facility) are sensitive to changes in these parameters.

1. Increases in isolated facility design capacity show diminishing returns with respect to Isolated conveyance. A 5,000 cfs facility provides conveyance of approximately 1.8 MAF/year during the 1928-34 critical period and 3.0 MAF/year over the 1922-94 long-term period. Doubling the size of the facility provides an additional 0.4 MAF/year during the critical period and an additional 1.2 MAF/year over the long-term period. Increasing the design capacity from 10,000 cfs to 15,000 cfs provides little to no benefit during either period.

2. Relaxing the minimum thru-Delta conveyance from 3,000 cfs to 1,000 cfs during January, February and March provides additional isolated conveyance of 60-110 TAF/year during the critical period and 30-60 TAF/year during the long-term period. The larger benefits are associated with larger design capacities.

3. Complete relaxation of the ratio constraint provides additional isolated conveyance of 0-70 TAF/year during the critical period and 0-210 TAF/year during the long-term period. The larger benefits are associated with larger design capacities.

Table 1: Sensitivity Analysis of Dual Facilities Operational Criteria

Capacity (cfs)	Ratio	Min Thru-Delta (cfs)	Water Supply Benefit (TAF/year) [4]		Isolated Conveyance (TAF/year)	
			28-34	22-94	28-34	22-94
5,000 [1]	0.7	3,000	80	110	1760	2990
10,000 [2]	0.7	3,000	80	110	2170	4180
15,000 [2]	0.7	3,000	80	120	2180	4180
5,000 [1]	0.7	3,000/1,000 [3]	80	110	1820	3020
10,000 [2]	0.7	3,000/1,000 [3]	80	110	2280	4230
15,000 [2]	0.7	3,000/1,000 [3]	80	120	2290	4240
5,000 [1]	1.0	3,000	80	110	1760	2990
10,000 [2]	1.0	3,000	80	110	2200	4250
15,000 [2]	1.0	3,000	80	120	2250	4390

notes:
[1] Delta cross channel closed September - November
[2] Delta cross channel closed September - December
[3] lower minimum imposed January - March only
[4] water supply benefits are measured against Study 472B

PRELIMINARY RESULTS: WATER SUPPLY BENEFITS

Water supply benefits are defined as the additional water supply provided by the alternative over the benchmark conditions (Study 472). Water supply benefits are reported in Table 2 for the 1928-34 critically dry period and the 1922-94 average period.

Table 2: Preliminary Water Supply Benefits of CALFED Facilities

Study Number	Facility Description	Water Supply Benefit (TAF/yr) 1928-34	1922-94
472B	SDI	80	200
472E	Max Wheeling	0	30
472F	SDI + Max Wheeling	80	280
475	SDI + 5,000 cfs IF	160	310
493	SDI + 15,000 cfs IF	160	320

D-005494

APPENDIX I
DWRSIM STUDIES MATRIX FOR CALFED STORAGE & CONVEYANCE

ALT	DWRSIM ID#	DWRSIM Version	DESCRIPTION	STATUS	WEBSITE
1	472	8.41	Benchmark	complete	public
1B	472E	8.41	Benchmark w/ max wheeling	complete	private
2	472B	8.41	Benchmark w/ SDI	complete	public
2B	472F	8.41	472B w/ max wheeling	complete	private
3	475	8.41	472B w/ 5,000 cfs IF	complete	N/A
4	493	8.41	472B w/ 15,000 cfs IF	complete	N/A
5	494	8.41	Benchmark w/ 3MAF NDSS	complete	N/A
6	495	8.41	472B w/ 3MAF NDSS	in progress	N/A
7	496	8.41	475 w/ 3MAF NDSS	in progress	N/A
8	497	8.41	472 w/ 2MAF SDSS	in progress	N/A
9	498	8.41	472B w/ 2MAF SDSS	in progress	N/A
10	499	8.41	475 w/ 2MAF SDSS	in progress	N/A
11	500	8.41	475 w/ NDSS & SDSS	in progress	N/A

1."Benchmark" meets WQCP objectives and selected upstream ESA requirements and CVPIA flow prescriptions with 2020 level south-of-Delta demands.

1B. Study 472 plus CVP water is wheeled through Banks to meet unmet demands and to fill San Luis Reservoir when capacity is available.

2. Study 472 plus facilities required to obtain a permit to operate Banks at 10,300 cfs capacity.

2B. Study 472B plus CVP water is wheeled through Banks to meet unmet demands and to fill San Luis Reservoir when capacity is available.

3. Study 472B plus a 5,000 cfs Isolated Facility that serves Banks and Tracy. Minimum thru-Delta conveyance is 100% of Banks and Tracy export or 3,000 cfs, whichever is less. Facility conveyance does not exceed 70% of Banks and Tracy export and is excluded from the definition of "Delta inflow" and "Delta export" in the February-June and April-May export restrictions.

4. Same as Study 475 except the Isolated Facility has a 15,000 cfs capacity.

5. Study 472 plus a 3.0 MAF north-of-Delta surface storage facility with 5,000 cfs inflow/outflow capacity.

6. Study 472B plus a 3.0 MAF north-of-Delta surface storage facility with 5,000 cfs inflow/outflow capacity.

7. Study 475 plus a 3.0 MAF north-of-Delta surface storage facility with 5,000 cfs inflow/outflow capacity.

8. Study 472 plus a 2.0 MAF south-of-Delta surface storage facility with 3,500 cfs inflow/outflow capacity.

9. Study 472B plus a 2.0 MAF south-of-Delta surface storage facility with 3,500 cfs inflow/outflow capacity.

10. Study 475 plus a 2.0 MAF south-of-Delta surface storage facility with 3,500 cfs inflow/outflow capacity.

11. Study 475 plus (i) a 3.0 MAF north-of-Delta surface storage facility with 5,000 cfs inflow/outflow capacity and (ii) a 2.0 MAF south-of-Delta surface storage facility with 3,500 cfs inflow/outflow capacity.

APPENDIX II
DWR PLANNING SIMULATION MODEL (DWRSIM) ASSUMPTIONS FOR
CALFED BENCHMARK STUDY
1995C6F-CALFED-472

Study 472 meets SWRCB'S May 1995 Water Quality Control Plan (Plan) and includes selected upstream ESA requirements and CVPIA flow prescriptions (see Item III). Assumptions are identical to Study 471 (B160-98 Public Draft) except than 2020 level South-of-Delta demands are assumed.

I. New Model Features

A new DWRSIM version with the following enhancements is employed:

A. A new SWP and CVP south-of-Delta delivery logic uses (i) runoff forecast information and uncertainty (not perfect foresight), (ii) a delivery versus carryover risk curve and (iii) a standardized rule (Water Supply Index versus Demand Index Curve) to estimate the total water available for delivery and carryover storage. The new logic updates delivery levels monthly from January 1 through May 1 as water supply parameters become more certain. Refer to Leaf and Arora (1996) for additional information on the new delivery logic.

B. An expanded network schematic includes more details in the Delta and along the DMC and SWP-CVP Joint Reach facility.

C. A network representation of the San Joaquin River basin was adapted from USBR's SANJASM model. The San Joaquin River basin schematic was expanded to include (i) the Tuolumne River upstream to Hetch Hetchy and Cherry/Eleanor Reservoirs, (ii) the Merced River upstream to Lake McClure, (iii) the Chowchilla and Fresno Rivers upstream to Eastman and Hensley Lakes, respectively, and (iv) the San Joaquin River upstream to Millerton Lake.

D. Contra Costa Water District's "G" model is used to relate Delta flows and salinities. Refer to Denton (1993) for additional information on the procedure.

E. References:

Leaf, R.T. and Arora, S.K. (1996). "Annual Delivery Decisions in the Simulation of the California State Water Project and Federal Central Valley Project using DWRSIM." *Proceedings 1996 North American Water and Environment Congress*, ASCE, C.T. Bathala, Ed.

Denton, R.A. (1993). "Accounting for Antecedent Conditions in Seawater Intrusion Modeling - Applications for the San Francisco Bay-Delta." *Proceedings 1993 National Conference on Hydraulic Engineering*, ASCE, H.W. Shen, Ed.

II. Instream Flow Requirements

A. Trinity River minimum fish flows below Lewiston Dam are maintained at 340 TAF/year for all years, based on a May 1991 letter agreement between the USBR and the U.S. Fish and Wildlife Service.

B. Sacramento River navigation control point (NCP) flows are maintained at 5,000 cfs in wet and above normal water years and 4,000 cfs in all other years. This criterion is relaxed to 3,500 cfs when Shasta carryover storage drops below 1.9 MAF and is further relaxed to 3,250 cfs when Shasta carryover storage drops below 1.2 MAF.

C. Feather River fishery flows are maintained per an agreement between DWR and the Calif. Dept. of Fish & Game (August 26, 1983). In normal years these minimum flows are 1,700 cfs from October through March and 1,000 cfs from April through September. Lower minimum flows are allowed in low runoff years and when Oroville storage drops below 1.5 MAF. A maximum flow restriction of 2,500 cfs for October and November is maintained per the agreement criteria.

D. Stanislaus River minimum fish flows below New Melones Reservoir range from 98 TAF/year up to 302 TAF/year, according to the interim agreement (dated June 1987) between the USBR and the Calif. Dept. of Fish & Game. The actual minimum fish flow for each year is based on the water supply available for that year. Additional minimum flow requirements are imposed in June through September (15.2 - 17.4 TAF per month) to maintain dissolved oxygen levels in the Stanislaus River. Channel capacity below Goodwin Dam is assumed to be 8,000 cfs. CVP contract demands above Goodwin Dam are met as a function of New Melones Reservoir storage and inflow per an April 26, 1996 letter from USBR to SWRCB.

E. Tuolumne River minimum fishery flows below New Don Pedro Dam are maintained per an agreement between Turlock and Modesto Irrigation Districts, City of San Francisco, Dept. of Fish & Game and others (FERC Agreement 2299). Base flows range from 50 cfs to 300 cfs. Base and pulse flow volumes depend on time of the year and water year type.

F. Instream flow requirements are maintained in accordance with CVPIA criteria (see Item III) at the following locations: below Keswick Dam on the Sacramento River, below Whiskeytown Dam on Clear Creek and below Nimbus Dam on the American River.

III. CVPIA Flow Criteria

The following CVPIA flow criteria are in accordance with an April 26, 1996 letter from USBR to SWRCB. (This information is preliminary. It is envisioned that when significant changes occur within the CVP/SWP system, the criteria will be reviewed and possibly revised):

A. Flow objectives between 3,250 cfs and 5,500 cfs are maintained below Keswick Dam on the Sacramento River. Flow requirements during October through April are triggered by Shasta carryover storage.

B. Flow objectives between 52 cfs and 200 cfs are maintained below Whiskeytown Dam on Clear Creek, depending on month and year type.

C. Flow objectives between 250 cfs and 4,500 cfs are maintained below Nimbus Dam on the American River. Flow requirements during October through February are triggered by Folsom carryover storage. Flow requirements in other months are triggered by previous month storage plus remaining water year inflows.

IV. Trinity River Imports

Imports from Clair Engle Reservoir to Whiskeytown Reservoir (up to a 3,300 cfs maximum) are specified according to USBR criteria. Imports vary according to month and previous month Clair Engle storage.

V. Hydrology (HYD-C06F)

A new 1995 level hydrology, HYD-C06F, was developed similar to HYD-C06B described in a June 1994 memorandum report entitled "Summary of Hydrologies at the 1990, 1995, 2000, 2010 and 2020 Levels of Development for Use in DWRSIM Planning Studies" published by DWR's Division of Planning. HYD-CO6B was based on DWR Bulletin 160-93 land use projections and simulates the 71 year period 1922-92. HYD-C06F, developed through consultation with USBR to address differences in San Joaquin basin hydrology, simulates two additional years (through 1994) and includes the following major modifications compared to HYD-C06B:

A. Stand-alone HEC-3 models of the American, Yuba and Bear River subsystems were updated and extended through 1994. Yuba River minimum fishery flows below Bullards Bar Dam were not modified to reflect new FERC requirements. According to consultants for the Yuba County Water Agency, water supply impacts of the new requirements are not substantially different from those modeled in HYD-C06B.

B. Mokelumne River minimum fishery flows below Camanche Dam are modeled in HYD-C06F per an agreement between EBMUD, U.S. Fish and Wildlife Service, and Calif. Dept. of Fish & Game (FERC Agreement 2916). Base flows range from 100 cfs to 325 cfs from October through June, depending on time of the year and water year type. Base flows are maintained at 100 cfs from July through September for all water year types. Water year types are determined by reservoir storage and unimpaired runoff. For the months of April through June, additional pulse flows are maintained up to 200 cfs depending on water year type and reservoir storage.

C. Historical 1993-94 land use was estimated by linear interpolation between 1990 and 2000 normalized projected levels.

VI. Pumping Plant Capacities, Coordinated Operation & Wheeling

A. SWP Banks Pumping Plant average monthly capacity with 4 new pumps is 6,680 cfs (or 8,500 cfs in some winter months) in accordance with USACE October 31, 1981 Public Notice criteria.

B. CVP Tracy Pumping Plant capacity is 4,600 cfs, but physical constraints along the Delta Mendota Canal and at the relift pumps (to O'Neil Forebay) can restrict export capacity as low as 4,200 cfs.

C. CVP/SWP sharing of responsibility for the coordinated operation of the two projects is maintained per the Coordinated Operation Agreement (COA). Storage withdrawals for in-basin use are split 75 percent CVP and 25 percent SWP. Unstored flows for storage and export are split 55 percent CVP and 45 percent SWP. In months when the export-inflow ratio limits Delta exports, the allowable export is shared equally between the CVP and SWP. (The COA sharing formula is based on D-1485 operations, not on May 1995 Water Quality Control Plan operations. The sharing formula will likely be modified to conform with Water Quality Control Plan operations. Such a change has unknown, but potentially significant, operational implications.)

D. CVP water is wheeled to meet Cross Valley Canal demands when unused capacity is available in Banks Pumping Plant.

E. Enlarged East Branch aqueduct capacities are assumed from Alamo Powerplant to Devil Canyon Powerplant.

VII. Target Reservoir Storage

A. Shasta Reservoir carryover storage is maintained at or above 1.9 MAF in all normal water years for winter-run salmon protection per the NMFS biological opinion. However, in critical years following critical years, storage is allowed to fall below 1.9 MAF.

B. Folsom Reservoir storage capacity was reduced from 1010 TAF down to 975 TAF due to sediment accumulation as calculated from a 1992 reservoir capacity survey.

C. Folsom flood control criteria are in accordance with the December 1993 USACE report "Folsom Dam And Lake Operation Evaluation". This criteria uses available storage in upstream reservoirs such that the maximum flood control reservation varies from 400 TAF to 670 TAF.

VIII. SWP Demands, Deliveries & Deficiencies

A. 2020 demand level is assumed to be fixed at full entitlement of 4.2 MAF. MWDSC's monthly demand patterns assume an Eastside Reservoir and an Inland Feeder pipeline in accordance with a July 26, 1995 memorandum from MWDSC.

B. Deficiencies are imposed as needed per the draft "Monterey Agreement" criteria and are calculated from the following Table A entitlements for year 2020:

Agricultural Entitlements	1,175 TAF/year
M & I Entitlements	2,958
Recreation & Losses	64
Total Entitlements	4,197 TAF/year

C. When available, "interruptible" water is delivered to SWP south-of-Delta contractors in accordance with the following assumptions based on the Monterey Amendment White Paper redraft dated September 28, 1995:

1. Interruptible water results from direct diversions from Banks Pumping Plant. It is not stored in San Luis Reservoir for later delivery to contractors.

2. A contractor may accept interruptible water in addition to its monthly scheduled entitlement water. Therefore, the contractor may receive water above its Table A amount for the year. Interruptible water deliveries do not impact entitlement water allocations.

3. If demand for interruptible water is greater than supply in any month, the supply is allocated in proportion to the Table A entitlements of those contractors requesting interruptible water.

IX. CVP Demands, Deliveries & Deficiencies

A. 2020 level CVP demands, including canal losses but excluding San Joaquin Valley wildlife refuges are assumed as follows (see Item IX.B below for refuge demands):

Contra Costa Canal	=	202 TAF/year
DMC and Exchange	=	1,561
CVP San Luis Unit	=	1,447
San Felipe Unit	=	196
Cross Valley Canal	=	128
Total CVP Delta Exports	=	3,534 TAF/year

Including wildlife refuges, total CVP demand is 3,822 TAF/year. The Contra Costa Canal monthly demand pattern assumes Los Vaqueros operations in accordance with a July 11, 1994 e-mail from CCWD.

B. Sacramento Valley refuge demands are modeled implicitly in the hydrology through rice field and duck club operations. Sacramento Valley refuges include Gray Lodge, Modoc, Sacramento, Delevan, Colusa and Sutter. Level II refuge demands in the San Joaquin Valley are explicitly modeled at an assigned level of 288 TAF/year. San Joaquin Valley refuges include Grasslands, Volta, Los Banos, Kesterson, San Luis, Mendota, Pixley, Kern and those included in the San Joaquin Basin Action Plan.

C. CVP south-of-Delta deficiencies are imposed when needed by contract priority. Contracts are classified into four groups: agricultural (Ag), municipal and industrial (M&I), Exchange and Refuge. Deficiencies are imposed in accordance with the Shasta Index and sequentially according to the following rules:

1. Ag requests are reduced up to a maximum of 50 percent.

2. Ag, M&I and Exchange requests are reduced by equal percentages up to a maximum of 25 percent. At this point, cumulative Ag deficiencies are 75 percent.

3. Ag, M&I and Refuge requests are reduced by equal percentages up to a maximum of 25 percent. At this point, cumulative Ag and M&I deficiencies are 100 percent and 50 percent, respectively.

4. M&I requests are reduced until cumulative deficiencies are 100 percent.

5. Further reductions are imposed equally upon Exchange and Refuge.

D. Deficiencies in the form of "dedicated" water and "acquired" water to meet 800 TAF/year CVPIA demands are not imposed.

X. Delta Standards

In the following assumptions related to Delta standards, reference is made to the SWRCB's May 1995 Water Quality Control Plan (Plan):

A. Water Year Classifications

1. The Sacramento Valley 40-30-30 Index (as defined on page 23 of the Plan) is used to determine year types for Delta outflow criteria and Sacramento River system requirements unless otherwise specified in the Plan.

2. The San Joaquin Valley 60-20-20 Index (page 24) is used to determine year types for flow requirements at Vernalis.

3. The Sacramento River Index, or SRI (Footnote 6, page 20), is used to trigger relaxation criteria related to May-June Net Delta Outflow Index (NDOI) and salinity in the San Joaquin River and western Suisun Marsh.

4. The Eight River Index (Footnote 13, page 20) is used to trigger criteria related to (i) January NDOI, (ii) February-June X2 standards and (iii) February export ratio.

B. M&I Water Quality Objectives (Table 1, page 16)

1. The water quality objective at Contra Costa Canal intake is maintained in accordance with the Plan. A "buffer" was added to insure that the standard is maintained on a daily basis. Thus, DWRSIM uses a value of 130 mg/L for the 150 mg/L standard and a value of 225 mg/L for the 250 mg/L standard.

2. The M&I water quality objectives at Clifton Court Forebay, Tracy Pumping Plant, Barker Slough and Cache Slough are not modeled.

C. Agricultural Water Quality Objectives (Table 2, page 17)

1. Water quality objectives on the Sacramento River at Emmaton and on the San Joaquin River at Jersey Point are maintained in accordance with the Plan.

2. Plan water quality objectives on the San Joaquin River at Vernalis are 0.7 EC in April through August and 1.0 EC in other months. These objectives are maintained primarily by releasing water from New Melones Reservoir. A cap on water quality releases is imposed per criteria outlined in an April 26, 1996 letter from USBR to SWRCB. The cap varies between 70 TAF/year and 200 TAF/year, depending on New Melones storage and projected inflow.

3. The interior Delta standards on the Mokelumne River (at Terminous) and on the San Joaquin River (at San Andreas Landing) are not modeled.

4. The export area 1.0 EC standards at Clifton Court Forebay and Tracy Pumping Plant are not modeled.

D. Fish & Wildlife Water Quality Objectives: Salinity (Table 3, page 18)

1. The 0.44 EC standard is maintained at Jersey Point in April and May of all but critical years. Per Footnote 6 (page 20), this criteria is dropped in May if the projected SRI is less than 8.1 MAF. The salinity requirement at Prisoners Point is not modeled.

2. The following EC standards are maintained at Collinsville for eastern Suisun Marsh salinity control:

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
EC - Ave. High Tide	19.0	15.5	15.5	12.5	8.0	8.0	11.0	11.0

The corresponding EC standards for other locations in the eastern and western Suisun Marsh are not modeled.

E. Fish & Wildlife Water Quality Objectives: Delta Outflow (Table 3, page 19)

1. Minimum required NDOI (cfs) is maintained as follows:

Year Type	Oct	Nov	Dec	Jan	Feb-Jun	Jul	Aug	Sep
Wet	4,000	4,500	4,500	*	**	8,000	4,000	3,000
Above Normal	4,000	4,500	4,500	*	**	8,000	4,000	3,000
Below Normal	4,000	4,500	4,500	*	**	6,500	4,000	3,000
Dry	4,000	4,500	4,500	*	**	5,000	3,500	3,000
Critical	3,000	3,500	3,500	*	**	4,000	3,000	3,000

* January: Maintain either 4,500 cfs or 6,000 cfs if the December Eight River Index was greater than 800 TAF (per Footnote 13 page 20).

** February-June: Maintain 2.64 EC standards (X2) as described below.

2. For February through June, outflow requirements are maintained in accordance with the 2.64 EC criteria (also known as X2) using the required number of days at Chipps Island (74 km) and Roe Island (64 km). See Footnote 14 for Table 3 (Table A) page 26.

a. At the Confluence (81 km), the full 150 days (February 1 - June 30) of 2.64 EC is maintained in all years, up to a maximum required flow of 7,100 cfs. This requirement is dropped in May and June of any year for which the projected SRI is less than 8.1 MAF. In those years when the criteria is dropped, a minimum outflow of 4,000 cfs is maintained in May and June.

b. The criteria -- "If salinity/flow objectives are met for a greater number of days than the requirements for any month, the excess days shall be applied to meeting the requirements for the following month" -- is not modeled. See Footnote "a" of Footnote 14 for Table 3 (Table A).

c. The Kimmerer-Monismith monthly equation is used to calculate outflow required (in cfs) to maintain the EC standard (average monthly position in kilometers). In this equation the EC position is given and Delta outflow is solved for.

$$\text{EC position} = 122.2 + [0.3278 * (\text{previous month EC position in km})] - [17.65 * \log_{10}(\text{current month Delta outflow in cfs})]$$

In months when the EC standard is specified in more than one location (e.g. 19 days at the confluence and 12 days at Chipps Island), required outflow for the month is computed as a flow weighted average of the partial month standards.

3. Additional details on the 2.64 EC criteria are modeled as follows:

a. The trigger to activate the Roe Island standard is set at 66.3 km from the previous month, as an average monthly value.

b. The maximum required monthly outflows to meet the 2.64 EC standard are capped at the following limits: 29,200 cfs for Roe Island; 11,400 cfs for Chipps Island; and 7,100 cfs for the Confluence.

c. Relaxation criteria for the February Chipps Island standard is a function of the January Eight River Index as follows:

(i) X2 days = 0 if the Index is less than 0.8 MAF
(ii) X2 days = 28 if the Index is greater than 1.0 MAF

(iii) X2 days vary linearly between 0 and 28 if the Index is between 0.8 MAF and 1.0 MAF

F. Fish & Wildlife Water Quality Objectives: River Flows (Table 3, page 19)

1. Minimum Sacramento River flow requirements (cfs) at Rio Vista are maintained as follows:

Year Type	Sep	Oct	Nov	Dec
Wet	3,000	4,000	4,500	4,500
Above Normal	3,000	4,000	4,500	4,500
Below Normal	3,000	4,000	4,500	4,500
Dry	3,000	4,000	4,500	4,500
Critical	3,000	3,000	3,500	3,500

2. From February 1 through June 30, minimum flows on the San Joaquin River at Vernalis are maintained per the table below. For each period, the higher flow is required whenever the 2.64 EC Delta outflow position is located downstream of Chipps Island (<74 km). If the 2.64 EC Delta outflow position is upstream of Chipps Island (>74 km), then the lower flow requirement is used.

	Minimum Flows at Vernalis (cfs)	
Year Type	Feb1-Apr14 & May16-June30	April15-May15
Wet	2,130 or 3,420	7,330 or 8,620
Above Normal	2,130 or 3,420	5,730 or 7,020
Below Normal	1,420 or 2,280	4,620 or 5,480
Dry	1,420 or 2,280	4,020 or 4,880
Critical	710 or 1,140	3,110 or 3,540

3. For the month of October, the minimum flow requirement at Vernalis is 1,000 cfs in all years PLUS a 28 TAF pulse flow (per Footnote 19, page 21). The 28 TAF pulse (equivalent to 455 cfs monthly) is added to the actual Vernalis flow, up to a maximum of 2,000 cfs. The pulse flow requirement is not imposed in a critical year following a critical year. These two components are combined as an average monthly requirement as follows:

October Minimum Flows at Vernalis (cfs)

Base Flow	Required Flow
<1,000	1,455
1,000-1,545	Base Flow + 455
>1,545	2,000

4. The above flow requirements at Vernalis are maintained primarily by releasing additional water from New Melones Reservoir. In years when New Melones Reservoir

drops to a minimum storage of 80 TAF (per April 26, 1996 letter from USBR to SWRCB), additional water is provided equally from the Tuolumne and Merced River systems to meet the Vernalis flow requirements. If these sources are insufficient to meet objectives at Vernalis, nominal deficiencies will be applied to upstream demands.

G. Fish & Wildlife Water Quality Objectives: Export Limits (Table 3, page 19)

1. Ratios for maximum allowable Delta exports are specified as a percentage of total Delta inflow as follows:

Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
65	65	65	65	45-35	35	35	35	35	65	65	65

a. In February the export ratio is a function of the January Eight River Index per Footnote 25, page 22 as follows:

(i) 45% if the Jan. 8-River Index is less than 1.0 MAF
(ii) 35% if the Jan. 8-River Index is greater than 1.5 MAF
(iii) Varies linearly between 45% and 35% if the January Eight River Index is between 1.0 MAF and 1.5 MAF.

b. For this ratio criteria, total Delta exports are defined as the sum of pumping at the SWP Banks and CVP Tracy Pumping Plants. Total Delta inflow is calculated as the sum of river flows from the Sacramento River, Yolo Bypass, total from the Eastside stream group, and San Joaquin River inflow. Delta area precipitation and consumptive uses are not used in this ratio.

2. Based on Footnote 22 page 21, April and May total Delta export limitations are modeled as follows:

a. April 15 - May 15 exports are limited to 1,500 cfs OR 100 percent of the San Joaquin River flow at Vernalis, whichever is greater.

b. April 1-14 and May 16-31 export limits are controlled by either the export/inflow ratio (35%) or pumping plant capacity, whichever is smaller.

H. Fish & Wildlife Water Quality Objectives: Delta Cross Channel (Table 3, page 19)

1. The Delta Cross Channel (DCC) is closed 10 days in November, 15 days in December and 20 days in January for a total closure of 45 days per Footnote 26, page 22.

2. The DCC is fully closed from February 1 through May 20 of all years and is closed an additional 14 days between May 21 and June 15 per Footnote 27, page 22.

APPENDIX III
CALFED STORAGE & CONVEYANCE COMPONENTS: OPERATIONS CRITERIA

I. Isolated Component of Dual Transfer Facility

The Isolated Component of the Dual Transfer Facility (i.e. the Isolated Facility) is operated to maximize water quality benefits. In other words, the maximum amount of water is diverted into the Facility regardless of any additional upstream releases that may be required. Diversion into the Isolated Facility is governed by the following operations criteria:

A. Minimum Thru-Delta Conveyance: This is a user-specified minimum export that must be diverted from Delta channels before diversions through the Isolated Facility can be made.

B. Maximum Allowable Conveyance Through the Isolated Facility: This is a user-specified fraction of the net export that can be transferred through the Isolated Facility. The net export does not include export that is obtained by a release from the In-Delta Storage Facility.

C. Isolated Facility Capacity Constraint: This is the user-specified physical capacity of the Isolated Facility.

D. Service to SWP Only: This is a user-specified option to operate the facility only for SWP net export. If selected, conveyance through the Isolated Facility is further limited to the SWP net export, excluding wheeling for the CVP.

E. Export Ratio Restrictions: This is a user-specified option that allows Isolated Facility conveyance to be included or excluded from Delta "inflow" and "export" computations for the February-June export restriction and the April-May export restriction.

II. In-Delta & North of Delta Storage Components

The In-Delta Storage facility (IDS), the North of Delta Surface Storage facility (NDSS), and the North of Delta Groundwater Storage facility (NDGS) are operated based on the following criteria:

A. Releases from IDS, NDSS and NDGS are restricted as follows:

1. Additional releases from IDS, NDGS, NDSS and Oroville storage are made only to satisfy the SWP share of Delta In-Basin requirements and SWP export.

2. Release is made first from IDS. The IDS release is limited by available storage and by a user-specified maximum release capacity. Releases are made only to reduce SWP releases from upstream storage facilities and only up to the amount that is required for SWP export. Releases from IDS are not considered in export ratio calculations. Releases are not made as an alternative to cutting export under the export ratio constraint.

3. Extraction/Releases are then made from NDGS, NDSS and Oroville storage. Extraction/Release from NDGS and NDSS are balanced with the Oroville release in the HEC III manner (i.e. balancing based on user specified logical levels). This balancing technique is flexible enough to consider a very wide range of priorities.

4. Extraction/Release from NDGS and NDSS are limited by the user-specified aquifer/reservoir extraction/outlet capacities..

B. Natural recharge of the NDGS is calculated as a user-specified percentage of the available storage capacity at the beginning of the month. The resulting recharge is considered as a Sacramento River basin requirement.

C. Artificial recharge of NDGS and filling of NDSS and IDS facilities is restricted as follows:

1. In each water year, artificial recharge of NDGS and filling of NDSS will not be permitted until a flushing volume of at least 550 TAF in one month occurs at the diversion point for filling of NDSS. In determining the artificial recharge of NDGS and the filling of NDSS for the month in which the flushing volume occurs, only Sacramento River flow in excess of the 550 TAF/month flow at each respective diversion will be considered for use in recharging/filling the facilities.

2. If any releases are being made to satisfy Delta In-Basin requirements, artificial recharge of NDGS and filling of NDSS and IDS will not be permitted.

3. Only Sacramento River inflow into the Delta that is in excess of the export ratio requirement and is also surplus Delta outflow is considered for use in the artificial recharge of NDGS and filling of NDSS and IDS.

4. The artificial recharge of NDGS is considered first. Artificial recharge of NDGS is limited to the excess Sacramento River flow above any required river flow between its diversion point and the point of inflow into the Delta. It is also limited to its available unfilled capacity and a user- specified maximum recharge rate.

5. The filling of NDSS is considered second. Filling of NDSS is limited to the excess Sacramento River flow above any required river flow between its diversion point and the point of inflow into the Delta minus the diversion for the artificial recharge of the NDGS. It is also limited to its available unfilled capacity and a user-specified maximum fill rate.

6. The filling of IDS is considered third. Filling of IDS is limited to its available unfilled capacity and a user-specified maximum fill rate.

7. The filling of IDS is considered an export and is, therefore, subject to the export ratio requirement. Since filling IDS is using only surplus water (CVP has taken all it can) it is not subject to COA sharing.

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III. South of Delta Storage Components

The South of Delta Surface Storage facility (SDSS) and the South of Delta Groundwater Storage facility (SDGS) are operated based on the following criteria:

A. Storage capacities of SDSS and SDGS are user-specified.

B. Storage releases from SDSS and SDGS to meet downstream demands are restricted as follows:

> 1. The order of priority for storage releases is as follows: (a) SDGS, (b) SDSS and (c) SWP San Luis Reservoir.
>
> 2. Storage release capacities for SDSS and SDGS are user-specified.

C. Diversions to SDSS and SDGS are restricted as follows:

> 1. The order of priority for storage diversions is as follows: (a) SDGS, (b) SDSS and (c) SWP San Luis Reservoir.
>
> 2. Storage diversion capacities for SDSS and SDGS are user-specified.

D. SDSS operations (releases and diversions) are balanced with SWP San Luis operations.

E. SDSS and SWP San Luis operations are triggered by combined south of Delta target storage. This combined storage is filled during some high outflow periods and with storage transfers from upstream reservoirs.

F. Diversions (recharge) to SDGS are based on surplus outflow and storage transfer.

G. SDGS recharge and extraction are functions of SWP delivery and Oroville storage.

APPENDIX IV
INITIAL SENSITIVITY ANALYSIS OF DUAL DELTA TRANSFER FACILITIES

Sensitivity Analysis for Isolated Facility

Effects on Water Supply and Delta Outflow

Run #	IF Capacity	Min Export Through Delta	IF included in Ratio	XCG Position	CVP		SWP		Required	Delta
					Export	Shasta **	Export	Oroville **	MDO	Outflow
472					2555	2422	3198	1983	5428	12169
472B					2562	2426	3377	2054	5421	11958
1	5000	3000	no	open	32	-2	113	2	66	-137
2	5000	3000	no	closed	22	19	120	17	26	-143
3	5000	3000	yes	open	1	-1	-12	-9	31	14
4	5000	3000	yes	closed	4	12	-4	5	-11	-1
5	5000	1000	no	open	19	-38	84	-49	136	-96
6	5000	1000	no	closed	21	12	116	-1	34	-136
7	5000	1000	yes	open	-6	-23	-29	-38	90	42
8	5000	1000	yes	closed	9	11	-9	0	-2	0
9	5000	5000	no	open	17	1	115	26	48	-129
10	5000	5000	no	closed	18	10	119	23	20	-135
11	5000	5000	yes	open	0	0	-6	-1	11	7
12	5000	5000	yes	closed	4	12	-2	5	-15	-3
13	15000	1000	no	open	19	-38	84	-48	137	-95
14	15000	1000	no	closed	26	11	115	-1	35	-136
15	15000	1000	yes	open	-7	-23	-29	-38	90	42
16	15000	1000	yes	closed	8	11	-8	0	-1	0
				Average	**12**	**-2**	**48**	**-7**	**43**	**-57**
				Maximum	**32**	**19**	**120**	**26**	**137**	**42**
				Minimum	**-7**	**-38**	**-29**	**-49**	**-15**	**-143**

** End of Septamber carry over storage

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Sensitivity Analysis for Isolated Facility

Efftects of Excluding Flow through IF in Export Ratio

Run #	IF Capacity	Min Export Through Delta	XCG Position	IF included in Ratio *	CVP		SWP		Required	Delta
					Export	Shasta**	Export	Oroville**	MDO	Outflow
1	5000	3000	open	no	31	-1	125	11	35	-151
2	5000	3000	closed	no	18	7	124	12	37	-142
3	5000	3000	open	yes						
4	5000	3000	closed	yes						
5	5000	1000	open	no	25	-15	113	-11	46	-138
6	5000	1000	closed	no	12	1	125	-1	36	-136
7	5000	1000	open	yes						
8	5000	1000	closed	yes						
9	5000	5000	open	no	17	1	121	27	37	-136
10	5000	5000	closed	no	14	-2	121	18	35	-132
11	5000	5000	open	yes						
12	5000	5000	closed	yes						
13	15000	1000	open	no	26	-15	113	-10	47	-137
14	15000	1000	closed	no	18	0	123	-1	36	-136
15	15000	1000	open	yes						
16	15000	1000	closed	yes						
				Average	**20**	**-3**	**121**	**6**	**39**	**-139**

* "No" indicates all flow entering IF and being exported from IF is not included in export ratio calculation and export restrictions durring April / May Vernalis pulse period does not apply to IF flow

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Sensitivity Analysis for Isolated Facility

Efftects of Cross Channel Gate Operation

Run #	IF Capacity	Min Export Through Delta	IF included in Ratio	XCG * Position	CVP		SWP		Required MDO	Delta Outflow
					Export	Shasta **	Export	Oroville **		
1	5000	3000	no	open						
2	5000	3000	no	closed	-10	21	7	15	-40	-6
3	5000	3000	yes	open						
4	5000	3000	yes	closed	3	13	8	14	-42	-15
5	5000	1000	no	open						
6	5000	1000	no	closed	2	50	32	48	-102	-40
7	5000	1000	yes	open						
8	5000	1000	yes	closed	15	34	20	38	-92	-42
9	5000	5000	no	open						
10	5000	5000	no	closed	1	9	4	-3	-28	-6
11	5000	5000	yes	open						
12	5000	5000	yes	closed	4	12	4	6	-26	-10
13	15000	1000	no	open						
14	15000	1000	no	closed	7	49	31	47	-102	-41
15	15000	1000	yes	open						
16	15000	1000	yes	closed	15	34	21	38	-91	-42
				Average	**5**	**28**	**16**	**25**	**-65**	**-25**

*Additional XCG closure from June 5 through October 31

** End of Septamber carry over storage

D-005512

Sensitivity Analysis for Isolated Facility

Run #	IF Capacity	Min Export Through Delta	IF included in Ratio	XCG Position
1	5000	3000	no	open
2	5000	3000	no	closed
3	5000	3000	yes	open
4	5000	3000	yes	closed
5	5000	1000	no	open
6	5000	1000	no	closed
7	5000	1000	yes	open
8	5000	1000	yes	closed
9	5000	5000	no	open
10	5000	5000	no	closed
11	5000	5000	yes	open
12	5000	5000	yes	closed
13	15000	1000	no	open
14	15000	1000	no	closed
15	15000	1000	yes	open
16	15000	1000	yes	closed

- Joint CVP/SWP facility assumed for all runs
- Maximum export through IF is 70% assumed for all runs
- XCG position applies to June 5 through October 31 period only
- Exclusion of IF in export ration indicates all flow entering IF and being exported from IF is not included in export ratio calculation and export restrictions during April / May Vernalis pulse period does not apply to IF flow
- 1922 through 1942 period is used to determine all annual average results

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