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Storage and Conveyance Alternative Component Refinement Process

Prepared by the CALFED Storage and Conveyance Refinement Team
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I. Introduction

The purpose of the storage and conveyance component refinement process is to develop a range in which the storage and conveyance components are reasonably well balanced in capacities. By this we mean that the selected combination of components would operate efficiently over a normal range of hydrologic conditions, thus incurring the least cost and environmental impact associated with providing water supply opportunities. It is important to emphasize that the initial component choices in no way reflect an endorsement of or rejection of specific facilities. Increasingly detailed site and facility evaluations would take place in Phase II or Phase III of the process. In addition, a full range of operating assumptions and impact analyses will be evaluated in later phases as well.

The current refinement process evaluates various storage and conveyance components, including north of Delta surface and groundwater storage, through-Delta and dual transfer conveyance, in-Delta storage, and south of Delta surface and groundwater storage. The effect of various combinations of these components, added to the existing water management infrastructure, will be initially simulated using DWRSIM.

As a starting point, the combination of facilities shown in Table 1 will be simulated using DWRSIM. Based on the preliminary results of these simulations, further changes and refinements will be made to achieve balanced combinations of components.

During this refinement process it is impossible to anticipate what changes in operational rules may eventually be selected for operating the system to achieve environmental and water supply objectives. As a starting point for the initial analysis, it was assumed that the system would be operated according to existing rules, including the May 1995 Water Quality Control Plan. Additional assumptions were required to operate the proposed additional storage and conveyance components. These assumptions are set forth in the attached **"DWR Planning Simulation Model (DWRSIM) Assumptions for CALFED Conveyance/Storage Component Refinement Studies"** and **"DWR Planning Simulation Model (DWRSIM) Assumptions for CALFED Benchmark Study 1995C6D-CALFED-472"**. There is substantial of uncertainty over future no-project conditions, including implementation of the Central Valley Project Improvement Act, Trinity River flow allocations, allocation of American River flows, coordinated operations of the SWP and the CVP, and third-party participation in the State Water Resources Control Board Water Quality Control Plan implementation. Pending resolution of these and other uncertainties, the Team felt that the most reasonable approach was to begin by assuming current constraints. Assumptions will be refined and modified over several iterations before a set of modeling

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asumptions is proposed for Phase II impact analysis. The following paragraphs provide some background regarding the Team's reasoning in arriving at these assumptions, as well as caveats regarding their intended use.

II. Water Supply Opportunities

The proposed surface and groundwater storage components north of the Delta would be filled only after existing needs for water are met, including in-basin consumptive use, in-stream flow requirements, and Delta protective standards. In addition, this analysis also assumes that further diversions from the Sacramento River system would not occur until adequate seasonal flushing flows had occurred. Such flows are assumed to help restore river gravels, to maintain the river meander zone above Chico Landing, and to move salmon smolts downstream. A preliminary evaluation of the historical record suggests that when Sacramento River flow at the latitude of Hamilton City (River mile 200) equal or exceed 550,000 acre feet in a given month, the river will experience peak flow in excess 60,000 cfs some time during the month. Thus for the sake of this preliminary analysis, a monthly flow equal to or greater than 550,000 acre feet will be used as a surrogate for flushing flow which can be used to initiate and simplify the modeling effort using DWRSIM (which is based on a monthly time step).

Accordingly, in deciding when to divert surface flows to storage in a particular water year, DWRSIM will test to make sure that all existing water requirements, including Delta standards, are met and that at least one monthly flow has exceeded 550 taf. The same rule would be applied to determine when flows could be diverted to groundwater storage. If flows are limiting, DWRSIM would give a higher priority to filling ground water storage reservoirs and second priority to filling surface water storage. The reason for this is that diversion rates to groundwater are often limited by the rates at which water can be injected or infiltrated to storage.

The above assumptions are just a starting point for the process of refinement and evaluation. There is a virtually boundless range of possible combinations of storage facilities, conveyance facilities, and operating rules. It is important that the process for development of operating rules reflect the input of the various CALFED agencies and stakeholders. These constraints should be developed as three to five packages to reflect various restoration themes. A clear and open process for formulating these sets of constraints through the various workgroups such as the Ecosystem Restoration Work Group and the Agency Ecosystem Review Team will assure that the appropriate interests and experts are represented.

III. Accounting for Water Supply Benefits and Impacts

It is likely that future storage and conveyance components would be integrated into both the State Water Project and Central Valley Project, with an effect on the water supply from both systems. At this point in the process, we really have no criteria for allocating the components between the two existing systems. Therefore it is assumed that the new components are all added to the SWP.

It is recognized that criteria for sharing resources between the between the SWP and CVP are uncertain under the May 1995 WQCP, and therefore this modeling approach will need to be carefully reviewed and modified for Phase II of the analysis.

Similarly, there are many ways to allocate new supplies between environmental, agricultural, and urban needs. Various allocation themes can be developed through open CALFED technical discussions and negotiations and bundled as alternative operating constraints. Water supply benefits and impacts can then be compared to specific targets. Until such bundles of criteria can be developed and translated into modeling assumptions, the incremental change in SWP supplies and increases in Delta outflow during balanced conditions will be taken as an index of net water supply available for all beneficial purposes.

IV. Conveyance Assumptions

The 1994 Bay-Delta Accord is based on the need to protect a wide range of beneficial uses, based on the existing configuration of the Bay-Delta system. A significant alteration of the existing through-Delta water supply system would likely require a re-evaluation both to assure that beneficial uses are protected and to assure that operating rules are not unnecessarily restrictive.

Among the most likely candidates for re-evaluation would be the Delta export limits, designed to limit entrainment of eggs, larvae, and fish at export facilities. If part of the inflow to the Delta is diverted through one or more screened intakes at the northern end of the Delta into an isolated conveyance channel, that portion of the inflow could be either counted as part of the Delta inflow or subtracted from the Delta inflow. Similarly, export flows taken through an isolated conveyance could be counted either way. Thus there are various ways to compute the new export-inflow ratio. The two most likely approaches would be to:

- Include the isolated component in both inflow and export when computing the ratio.

- Delete the isolated flow from both inflow and export when computing the ratio.

The current export limit for April 15 through May 15 is 1500 cfs or 100 % of the 3-day running average of San Joaquin River flow at Vernalis, whichever is greater. This standard is intended to limit entrainment of San Joaquin River salmon smolts during their out migration. Isolated diversions from the Sacramento River would likely not be expected to affect San Joaquin River smolts and it may therefore be logical to exclude isolated diversions when computing allowable exports.

The Team felt that the issue of how to account for the isolated export component required discussion among a broad group of stakeholders and agency policymakers. To facilitate that discussion and to gain some insight into the sensitivity of the system to changes in this criterion the simulations would be run both ways.

V. Surface Storage Facility Assumptions

In order to evaluate the performance of the various storage components we needed to assume specific locations, capacities, and operating rules for filling and emptying. For example, as a surrogate for north of Delta surface storage we assumed a reservoir in the foothills west of Colusa. For south of Delta surface storage, we assumed a reservoir in the vicinity of the existing San Luis Reservoir.

For in-Delta storage, specific islands were not selected. However, the assumption was made that the islands would be close enough to the SWP and CVP export facilities to provide direct connections through a series of siphons, thus eliminating the need to screen export water from this source twice.

It is important to emphasize that these choices in no way reflect an endorsement of or rejection of specific facilities. Detailed site and facility evaluations would not take place until Phase II or Phase III of the process.

VI. Groundwater Storage Facility Assumptions

Groundwater resources can be used to provide increased groundwater storage in several ways. One approach, referred to here as direct groundwater storage, involves treating groundwater basin like a surface water reservoir, except that it is filled by seepage from percolation basins or injection wells, and emptied by pumping from wells. This approach may involve high capital and operating costs, and is limited by the capacities of project facilities.

A second approach, referred to here as in-lieu groundwater storage, involves varying regional uses of groundwater and surface water resources such that surface water deliveries are supplemented in wet years and cut back in dry and critical years. This results in greater annual variations in groundwater use and storage. The net effect is to make greater stream flows available for other uses during dry and critical years. The in-lieu approach tends to be more practical and economical, because it takes advantage of water use patterns over large areas and existing water distribution and extraction facilities.

Both of these approaches will be evaluated for the areas upstream of the Delta during the component refinement process.

Direct Groundwater Storage

The evaluation of north of Delta groundwater resources was simplistic due to the lack of detailed

hydro-geologic information and lack of operational experience.

The overall approach for modeling direct groundwater storage in the Sacramento Valley was to identify areas in which natural recharge through seepage from nearby streams was relatively slow. During this refinement process it is premature to model specific storage areas; rather it was assumed that the groundwater basins could be simulated as a single basin, with composite recharge, storage, and discharge characteristics. This basin would be incorporated into DWRSIM through a single node, through which flow project recharge, non-project recharge, and pumped withdrawals from storage.

A maximum of 500,000 acre-feet of operable groundwater storage capacity was assumed. A maximum project recharge rate of 500 cfs and discharge rate of 1000 cfs were assumed. In addition, the total non-project recharge capacity was limited to less than the full 500,000 acre-feet to reflect hydrogeologic constraints.

Non-project recharge will be accounted for in project operations whenever the groundwater basins are only partly filled. The rate of recharge is greatest when the groundwater basin is depleted, then diminishes as it fills. These rules crudely simulate the natural recharge pattern. Whenever artificial recharge occurs, the simulated volume of water in storage is updated, and the natural recharge rate adjusted downward accordingly.

Implementation of groundwater storage components which rely on direct withdrawal of groundwater for export from the Sacramento Valley would need to be coordinated with institutional constraints such as Sect 1220 of the Water Code. This Section prohibits groundwater extraction from the Sacramento Valley for export, unless certain conditions are met.

For south of Delta groundwater storage it was assumed that simulating a groundwater storage basin underlying the Kern River fan would provide insight into the potential effects on water supply opportunities. Such facilities have been described in detail elsewhere and the description is not repeated here.

In-Lieu Groundwater Storage

This option involves altering delivery patterns to areas where surface water and ground water resources are both used for irrigated agriculture. In wet years additional surface water would be delivered, allowing groundwater resources to accumulate; in dry and critical years surface water deliveries would be reduced, resulting in a greater use of groundwater storage in meeting total demands.

Various approaches to modeling conjunctive use within DWRSIM have been considered. The most promising approach would involve modifying the input hydrology files for one or more of

the Depletion Areas. The demand pattern would have the same shape as the existing pattern within a given DA; only the annual volume would be adjusted.

The demand during wet years (based on the Sacramento River Index) would be increased to reflect increased surface deliveries, while the demand during dry and critical years would be reduced to reflect increased groundwater use. The current hydrologic record has about 20% wet and 20% dry and critical years.

As a starting point for evaluation, 100 TAF would be exercised in any given year. Subsequent evaluations could look at 200, 300, and greater annual volumes. Due to non-project seepage, additional reservoir releases would be required to transport a given water volume. For example, to deliver 100 TAF, a release of 125 TAF might be required. The 25 TAF would offset non-project recharge.

The net effect of any program which exercises groundwater storage would be a reduction in the long-term average groundwater level (except in areas where groundwater levels are already depressed due to overdraft). Therefore a key criterion for implementation would be that there be no long-term unmitigated effects.

The simulation approach would be similar for both the Sacramento Valley and the San Joaquin Valley.

Table 1.
Conveyance and Storage Simulation Studies--Initial Set

Component	Bench-mark	Run 1, max. Dual	Run 2, Thru-Delta	Run 3, Isolated Conv.	Run 4, Small Dual	Run 5, Medium Dual
Through-Delta Conveyance, cfs	Existing	Existing	15,000	0	Existing	Existing
Isolated Facility Conveyance, cfs	--------	15,000	0	15,000	5,000	10,000
Surface Storage, taf						
Tributary	-------					
Sacramento Valley	-------	3,000	3,000	0	0	1,500
San Joaquin Valley	-------					
In-Delta	-------	400	400	0	0	200
Off Aqueduct	-------	1,500	1,500	0	1,500	750
Groundwater Storage, taf						
Tributary	-------	500	500	0	0	250
Off-Aqueduct	-------	500	500	0	500	250

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PRELIMINARY DRAFT - SUBJECT TO REVISION

DWR PLANNING SIMULATION MODEL (DWRSIM) ASSUMPTIONS FOR CALFED CONVEYANCE/STORAGE COMPONENT REFINEMENT STUDIES

The following assumptions overlay CALFED Benchmark Study 472:

I. SYSTEM DESCRIPTION

The modeled system includes all existing CVP and SWP facilities and various combinations of the following CALFED conveyance/storage components. For modeling convenience, these components are assumed to be SWP facilities.

A. H.O. Banks Pumping Plant Improvements (BPPI): Facilities required to obtain a permit to operate Banks Pumping Plant at 10,300 cfs capacity are assumed. (Not included in Benchmark run).

B. North-of-Delta Surface Storage (NDSS): This facility diverts spills and unregulated flows from Shasta and/or Oroville Reservoirs. Facility location is assumed in the foothills west of Colusa.

C. North-of-Delta Groundwater Storage (NDGS): The groundwater storage facilities are modeled as a single basin with composite hydrogeologic characteristics. Facility location is assumed north of Sacramento.

D. Delta Conveyance (DC): Conveyance is provided through existing Delta channels and/or an isolated facility at in the vicinity of Hood. State-of-the-art screening is assumed such that facility operations are not restricted by "take" limits. It is further assumed that operational flexibility would be maintained under a "no net water supply cost" provision managed by the CALFED operations group.

E. In-Delta Storage (IDS): Three or more islands provide in-Delta storage. These islands are physically linked to Clifton Court Forebay.

F. South-of-Delta Surface Storage (SDSS): Facility location is assumed near the existing San Luis Reservoir.

G. South-of-Delta Groundwater Storage (SDGW): Facility location is assumed on the Kern River fan.

II. SYSTEM STORAGE AND RELEASE CONSIDERATIONS

A. In any year, flows that follow a monthly "flushing" volume of at least 550 TAF may be diverted to NDSS, NDGS and IDS. All diversions are in accordance with SWRCB's May 1995 Water Quality Control Plan and selected upstream ESA and CVPIA flow criteria. Diversions are also subject to facility diversion and storage capacities.

B. All new surface storage is included in system carryover. However, only a fraction of new groundwater storage is included in system carryover. The Benchmark study delivery-carryover storage curve is modified to account for increased carryover with added facilities.

C. The order of priority for operation of storage diversions upstream of export facilities is as follows: (1) NDGS, (2) NDSS and (3) IDS. The order of priority for storage diversions downstream of export facilities is as follows: (1) SDGS, (2) SDSS and (3) SWP San Luis Reservoir.

D. The order of priority for storage releases to meet demands is as follows: (1) IDS, (2) SDSS, (3) SDGS and (4) SWP San Luis Reservoir. The order of priority for storage transfer is as follows: (1) NDSS and (2) NDGS.

E. Oroville releases are balanced with NDSS releases.

F. SWP San Luis releases are balanced with SDSS releases.

III. OPERATION OF COMPONENT FACILITIES

A. North-of-Delta Surface Storage (NDSS)

1. Maximum and minimum reservoir storage capacities are 3 MAF and 50 TAF, respectively. Evaporation losses and local inflows are incorporated in reservoir operations.

2. Maximum reservoir diversion and release capacity is 5,000 cfs. Monthly diversion rates are a function of flows in excess of those required to meet existing standards and the monthly thresholds provided in Item IIA.

B. North-of-Delta Groundwater Storage (NDGS)

1. An operable capacity of 500 TAF is assumed.

2. Natural recharge from streamflow depletion is assumed to be a function of available storage capacity. The aggregate annual percentage of available storage applied in the five years subsequent to the last project withdrawal or recharge operation is assumed as follows: 25% in the first year, 14% in the second year, 10% in the third year, 7% in the fourth year and 5% in the fifth year.

3. A maximum recharge rate of 500 cfs and a maximum pumping rate of 1,000 cfs are assumed.

4. A maximum annual extraction of 425 TAF is assumed.

5. Net depletion of groundwater storage is not permitted over the study period.

C. Delta Conveyance Facilities (DC)

1. DC is modeled as a combination of through-Delta and isolated facility conveyance.

2. The size of existing cross channel gates is increased to accommodate higher conveyance through Delta channels.

3. The maximum capacity of the isolated component of DC is 15,000 cfs.

4. Monthly conveyance through the isolated component of DC can be limited to specified percentages of total Delta export to address south Delta water quality problems:

Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX

Alternatively, monthly minimum through-Delta flows can be specified.

5. Two export-inflow ratios will be considered when diversions are made through the isolated component of DC:

a. Diversion are excluded from Delta inflow and export computations.

b. Diversion are included in Delta inflow and export computations.

6. The May 1995 WQCP limits April 15 - May 15 Delta exports to 1,500 cfs or 100 percent of the San Joaquin River flow at Vernalis, whichever is greater. The isolated component of DC could be excluded from this constraint.

D. In-Delta Storage Facilities (IDS)

1. Diversions are classified as exports in the export-inflow ratio and follow the export-inflow ratio criteria.

2. Diversions are stored in accordance with the priorities outlined in Item IIC.

3. Maximum storage capacity is 400 TAF.

4. Maximum diversion and release capacity is 5,000 cfs.

5. Facilities are physically linked to Clifton Court Forebay through siphons. Therefore, releases from storage are not limited by the export-inflow ratio and do not require additional screening.

6. Evaporation losses are included in Delta consumptive use estimates.

E. South-of-Delta Surface Storage (SDSS)

1. Maximum and minimum reservoir storage capacities are 1.50 MAF and 50 TAF, respectively. Evaporation losses and local inflows are included in reservoir operations.

2. Maximum diversion and release capacity is 3,500 cfs.

3. San Luis (SWP) and SDSS operations are triggered by combined south-of-Delta target storage (South-of-Delta rule curve). This combined storage is filled during some high outflow periods and with storage transfer from upstream reservoirs.

4. First priority is given to SDSS diversions and releases when balancing with San Luis Reservoir operations (see Items IIC and IID).

F. South-of-Delta Groundwater Storage (SDGS)

1. Maximum storage capacity is 500 TAF.

2. Recharge operations are based on surplus Delta outflow and storage transfer.

3. Maximum recharge and extraction capacities are 500 cfs and 1,000 cfs, respectively.

4. Recharge and extraction are functions of SWP delivery and Oroville storage.

IV. CONVEYANCE/STORAGE COMPONENT REFINEMENT STUDIES

A. The following studies have been defined and exclude a BPPI component:

	Delta Conveyance (cfs)		Surface & Groundwater Storage (MAF)				
Study	Thru	Isolated	NDSS	IDS	SDSS	NDGS	SDGS
1995C6D-CALFED-473 (Alt 1)	existing	15,000	3.0	0.4	1.5	0.5	0.5
1995C6D-CALFED-474 (Alt 2)	15,000	0	3.0	0.4	1.5	0.5	0.5
1995C6D-CALFED-475 (Alt 3)	0	15,000	0	0	0	0	0
1995C6D-CALFED-476 (Alt 4)	existing	5,000	0	0	1.5	0	0.5
1995C6D-CALFED-477 (Alt 5)	existing	10,000	1.5	0.2	0.75	0.25	0.25

B. Alternatives 6-11 are similar to the benchmark study (Study 472) and the above component refinement studies, except that BPPI is included.

PRELIMINARY DRAFT - SUBJECT TO REVISION

DWR PLANNING SIMULATION MODEL (DWRSIM) ASSUMPTIONS FOR CALFED BENCHMARK STUDY

1995C6D-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. A new procedure, based on an artificial neural network algorithm, relates Delta flows and salinities. Refer to Sandhu and Finch (1996) for additional information on the new 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.

Sandhu, N. and Finch, R. (1996). "Emulation of DWRDSM using Artificial Neural Networks and Estimation of Sacramento River Flow from Salinity." *Proceedings 1996 North American Water and Environment Congress*, ASCE, C.T. Bathala, 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 4,000 cfs in critical years and 5,000 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 dry and critical water years. 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.

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 and it is envisioned that when significant changes occur within the CVP/SWP system the mandates and operations to implement the CVPIA will need review and possible revision):

A. Flow objectives between 3,250 cfs and 6,000 cfs are maintained below Keswick Dam on the Sacramento River. Flow requirements during October through April are triggered by Shasta carryover storage. Flow requirements in other months are triggered by previous month 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 500 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

A new 1995 level hydrology (HYD-C06D) was developed from a hydrology (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 for 71 years (1922-92). The new hydrology, HYD-C06D, was modified through consultation with USBR to address differences in San Joaquin basin hydrology and was extended two additional years (through 1994) with the following assumptions:

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-C06B 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. 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. 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. (This sharing formula is based on operations under D-1485, not the May 1995 WQCP. The COA sharing formula will likely be changed to be adapted to the 1995 WQCP with 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 4.1 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 1996 Table A entitlements:

Agricultural Entitlements	1,220 TAF/year
M & I Entitlements	2,851
Recreation & Losses	64
Total Entitlements	4,135 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 in accordance with Bulletin 160-93 (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

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 232 TAF/year. San Joaquin Valley refuges include Grasslands, Volta, Los Banos, Kesterson, San Luis, Merced, Mendota, Pixley and Kern.

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 Chipps Island for western Suisun Marsh salinity control:

		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
EC - Deficiency Period		19.0	16.5	15.6	15.6	15.6	15.6	14.0	12.5
EC - Other Period	19.0	16.5	15.5	12.5	8.0	8.0	11.0	11.0	

In the deficiency period (as defined by Footnote 9 page 20), the relaxation of EC standards is assumed to start in January and continues for a 12-month period through the following December. 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)	
	February 1 - April 14 and	
Year Type	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 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 Delta Cross Channel 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.