CHAPTER IV. ANALYTICAL METHODS

This chapter describes the principal analytical methods and models used by the SWRCB to evaluate the environmental effects of alternative methods of implementing the objectives. The chapter contains a description of (a) DWR's planning simulation model (DWRSIM) which was used to determine the water supply and hydrologic effects of the alternatives; (b) DWR's Delta hydrodynamics and water quality model (DWRDSM) which simulates the hydrodynamics and salinity in the Bay/Delta Estuary; (c) the City of Stockton's dissolved oxygen model which was used to calculate dissolved oxygen concentrations in the San Joaquin River near Stockton; (d) the San Joaquin River Input/Output (SJRIO) model which was used to determine the effects of water quality control actions on salinity and flow in the San Joaquin Basin; (e) the USBR water temperature model which was used to assess the effects of the alternatives on water temperature in the major streams tributary to the Delta; (f) aquatic resource relationships which were used to provide a qualitative comparison of relative abundance of aquatic resources under the alternatives; and (g) the methodology used to calculate the responsibility of parties under the water right priority alternatives (Alternatives 3 and 4 under the flow objectives alternatives).

A. DWRSIM

DWRSIM is a generalized planning model for California's Central Valley and the SWP/CVP project systems. The model is designed to simulate the river and reservoir system upstream of the Delta, Delta export operations, and the SWP and the CVP conveyance systems in the export areas. 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 Operations Agreement (COA) between the SWP and the CVP, and required minimum Delta operations to meet Delta water quality and outflow objectives. DWRSIM models most of the river systems and major tributary reservoirs in the Central Valley. In the Sacramento Basin, the model includes: (1) the Sacramento River upstream to Shasta Lake, (2) the Feather River upstream to Lake Oroville, and (3) the American River upstream to Folsom Lake. In the San Joaquin Basin, the model includes: (1) the San Joaquin River upstream to Millerton Lake, (2) the Chowchilla and Fresno rivers upstream to Eastman and Hensley lakes, respectively, (3) the Merced River upstream to Lake McClure, (4) the Tuolumne River upstream to New Don Pedro Reservoir, and (5) the Stanislaus River upstream to New Melones Reservoir. The model also includes Trinity River diversions into the Sacramento Basin from Clair Engle and Lewiston lakes. The remaining river and reservoir systems in the Central Valley are incorporated into a depletion analysis, which is an input to DWRSIM. The following export-related facilities are also modeled: the Delta-Mendota Canal, the South Bay Aqueduct, the Coastal Aqueduct, and the California Aqueduct including the SWP-CVP Joint Reach, San Luis Reservoir, and Pyramid, Castaic, Silverwood, and Perris lakes. Descriptions of the DWRSIM model and the hydrology development process for the model have been prepared by the DWR (Barnes and Chung 1986; DWR 1986, 1992a, 1994a).

DWRSIM has several limitations that require the exercise of caution when 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 are made to model any standard that is not formulated on a monthly basis. Peak storm flows, which are usually considerably higher than monthly average flows, cannot be modeled. In addition, a monthly time step can not assess short-term aspects of project operation, such as fluctuations in daily pumping rates, and their associated environmental effects.

2. The federal ESA limitations on Delta export pumping based on actual take levels for delta smelt and winter-run chinook salmon are not modeled due to lack of information on when conditions requiring export constraints might be imposed.

3. The CVPIA mandates that 600 to 800 TAF of CVP yield be allocated annually 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 is subject to the uncertainty of the CVPIA allocation.

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

5. The Depletion Analysis model, which provides hydrologic input to DWRSIM, accounts for use of ground water, but ground water itself is not physically modeled.

6. 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.

For any DWRSIM modeling study, the modeled conditions in a particular year will not conform with the observed conditions for the same year. This is because the purpose of the model is not to recreate historic conditions but to predict potential conditions for planning purposes. Even though the model uses unimpaired streamflows based on historic hydrology from 1922 to 1994, the consumptive use of water specified in the model is based on current or future demand level. Thus, superimposing current or future water demand on historic hydrology produces modeled exports and reservoir operations that are different from historic conditions. This is true even for recent years because the model optimizes reservoir and export operations for the entire period of record.

The following operations criteria and major assumptions are incorporated into all of the DWRSIM studies for the alternatives under consideration, unless specified otherwise as part of an alternative. A description of these and additional DWRSIM assumptions has been prepared by the DWR (DWR 1996a, 1996b).

Hydrology. DWRSIM operates on a monthly time basis and uses the historical 73-year hydrologic sequence of flows from water years 1922 through 1994 as input. The water year begins on October 1 and ends on September 30. The hydrologic sequence is adjusted to reflect the effect of estimated 1995-level land use patterns, which are based on land use projections from DWR Bulletin 160-93 (DWR 1994b). 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 Basin hydrology was adapted from the USBR's SANJASM model.

Instream Flow Requirements. Instream flow requirements are described below, excluding flow requirements imposed through the CVPIA that are described in the next section.

1. Trinity River minimum fish flows below Lewiston Dam are maintained at 340 TAF/year for all years, based on a May 1991 letter of agreement between the USBR and the USFWS.

2. Sacramento River minimum fishery flows below Keswick Dam are maintained per an agreement between the USBR and the DFG (as revised October 1981). These flows range from 2,300 to 3,900 cfs, depending on the time of year according to the USBR's Shasta criteria.

3. Sacramento River navigation control point flows are maintained at 4,000 cfs in critical years and 5,000 cfs in all other years. These criteria are relaxed to 3,500 cfs when Shasta carry-over storage drops below 1.9 MAF.

4. Feather River fishery flows are maintained according to an August 26, 1983 agreement between the DWR and the DFG. 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. If flows between October 15 and November 30 exceed 2,500 cfs, then flows through the end of March can decrease only 500 cfs from the high point.

5. Lower American River minimum fish and recreation flows are maintained per USBR operation criteria outlined in an April 26, 1996 letter from USBR to the SWRCB (USBR 1996). October through February flow requirements are based on available storage in Folsom

Reservoir. March through September flow requirements are based on storage and inflow to Folsom Reservoir.

6. Mokelumne River minimum fishery flows below Camanche Dam are maintained per an agreement between EBMUD, USFWS, and DFG (FERC Agreement 2916). These flows range from 100 cfs to 325 cfs from October 1 through June 30, depending on time of the year and water year type. Flows are maintained at 100 cfs from July 1 through September 30 for all water year types. Additional pulse flows of up to 200 cfs are also provided in April through June in some years depending on storage levels and water year type.

7. Stanislaus River minimum fish flows below New Melones Reservoir range from 98 TAF/year to 302 TAF/year, according to the interim agreement dated June 1987 between the USBR and the DFG. 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 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 (USBR 1996).

8. 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, DFG 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.

9. Merced River minimum fishery flows below New Exchequer are maintained per FERC agreement 2179. Minimum flow ranges from 16 cfs to 101 cfs. Minimum flow volumes depend on the time of the year and the water year type.

<u>CVPIA Flow Criteria</u>.

1. Flow requirements between 3,250 cfs and 5,500 cfs are maintained below Keswick Dam on the Sacramento River. Flow requirements during October through April are based on Shasta carry-over storage. Flow requirements during May through September are based on the previous month's storage.

2. Flow requirements between 52 cfs and 200 cfs are maintained below Whiskeytown Dam on Clear Creek, depending on time of year and year type.

3. Flow requirements below Nimbus Dam on the American River during October through February are triggered by Folsom carry-over storage. Flow requirements during March through September are triggered by the previous month's storage plus remaining water year

inflows. Minimum flows are maintained per USBR operation criteria outlined in an April 26, 1996 letter from USBR to the SWRCB (USBR 1996).

Target Reservoir Storage.

1. Shasta Reservoir carry-over storage is maintained at or above 1.9 MAF in all normal water years for winter-run chinook salmon protection per the NMFS biological opinion. However, in critical years following critical years, storage is allowed to fall to 1.2 MAF (and lower in extremely dry years).

2. Folsom Reservoir storage capacity is reduced from 1010 TAF to 975 TAF due to sediment accumulation as calculated from a 1992 reservoir capacity survey. Folsom Reservoir flood control criteria are in accordance with the December 1993 USCOE report "Folsom Dam and Lake Operation Evaluation." The maximum flood control reservation varies from 400 TAF to 670 TAF based on available storage in upstream reservoirs.

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

SWP and CVP Pumping. The SWP Banks Pumping Plant's capacity is 10,350 cfs. However, unless specified otherwise, average monthly pumping is limited to 6,680 cfs (or 8,500 cfs in some winter months). The CVP Tracy Pumping Plant's permitted capacity is 4,600 cfs, but constraints along the Delta-Mendota Canal and at the relift pumps to O'Neill Forebay restrict export capacity to 4,200 cfs during some months.

SWP and CVP Sharing Formula. The SWP and the CVP share responsibility for the coordinated operation of the two projects based on the COA. Storage withdrawals for in-basin use are split 75 percent CVP and 25 percent SWP, and surplus flows are split 55 percent CVP and 45 percent SWP. The present COA does not specify how Delta pumping capacity is to be shared when export restrictions under the Bay/Delta Plan objectives control project operations. A sharing ratio of 50 percent CVP and 50 percent SWP is used.

SWP Demands, Deliveries and Deficiencies.

1. Maximum SWP contractor deliveries are designed to vary in response to local wetness indices. As such, maximum deliveries are reduced in the wetter years, assuming greater availability of local water supplies. Deliveries to all San Joaquin Valley agricultural contractors are reduced in wetter years, using a wetness index developed from annual Kern River inflows to Lake Isabella, as follows:

	Dry/Avg	Above	Wet
Kern River flow (TAF)	<1,000	1,000-1,400	>1,400
Max. ag delivery (TAF)	1,175	1,100	915

Deliveries to Metropolitan Water District (MWD) are reduced in wetter years as follows, using a 10-station, two-year average precipitation index:

	Dry	Avg.	Above	Wet
So. Cal. precip. (in/year)	<15	15-17.9	18-20.9	>20.9
Max. MWD delivery (TAF)	1,433	1,183	883	783

Maximum deliveries to all other SWP municipal and industrial (M&I) contractors are not adjusted for a wetness index, and are set at 857 TAF/year in all years. As a result of the use of these wetness indices, the total maximum delivery to all SWP contractors varies by year, ranging between 3,529 TAF in the dry-average years down to 2,619 TAF in the wetter years, as follows:

	Dry/Avg.	Avg.	Above	Wet
Max. ag delivery	1,175	1,175	1,100	915
Max. MWD delivery	1,433	1,183	883	783
Max. other M&I delivery	857	857	857	857
Fixed losses & recreation	64	64	64	64
Total maximum SWP delivery	3,529	(total varies)		2,619

A range of maximum SWP deliveries are possible, as the two wetness indices are independent of each other. Thus, a given year may be classified as "average" for agricultural deliveries by the Kern River flow index, and also be classified as "above average" or "wet" for MWD deliveries by the Southern California precipitation index.

2. Coastal Aqueduct deliveries to Santa Barbara and San Luis Obispo counties are assumed to be zero at the present level of development, but full deliveries are assumed at future levels of development.

3. Deficiencies are imposed according to the draft Monterey Agreement criteria (Monterey 1994) and are calculated from the following entitlements:

Agricultural entitlements	1,175 TAF/year
M & I entitlements	2,869
Recreation & losses	64

Total entitlements	4,108 TAF/year

4. When available, interruptible water is delivered to SWP south-of-Delta contractors in accordance with the following assumptions (interruptible water deliveries are deliveries to SWP contractors in excess of their entitlements):

   a. Interruptible water cannot be stored in San Luis Reservoir for later delivery to contractors.

   b. A contractor may accept interruptible water in addition to its monthly scheduled entitlement water. Interruptible water deliveries do not impact entitlement water allocations.

   c. If demand for interruptible water is greater than supply in any month, the supply is allocated in proportion to the entitlements of the contractors requesting interruptible water. The maximum demand assumed for interruptible water is 84 TAF per month.

<u>CVP Demands, Deliveries & Deficiencies</u>.

1. 1995 level CVP export demands, including canal losses, are assumed as follows:

Contra Costa Canal	=	140 TAF/year
DMC and Exchange Contractors	=	1,561
CVP San Luis Unit	=	1,260
San Felipe Unit	=	196
Cross Valley Canal	=	128
Wildlife Refuges	=	288
Total CVP Delta Exports	=	3,573 TAF/year

   CVP Delta export demands are reduced in certain wet years in the San Joaquin River Basin when flood flows and flows from the James Bypass are available in the Mendota Pool to satisfy Exchange Contractor demand.

   The Cross Valley Canal demands are imposed in some of the alternatives for the combined use of points of diversion (JPOD Alternatives 3-8).

2. 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 assumed level of 288 TAF/year. San Joaquin refuges include Grasslands, Volta, Los Banos, Kesterson, San Luis, Merced, Mendota, Pixley and Kern.

3. CVP South-of-Delta deficiencies are imposed when needed by contract priority. Contracts are classified into four groups: agricultural, M&I, exchange, and refuge. Deficiencies are imposed in accordance with the Shasta Index and sequentially according to the following rules:

    a. Agricultural requests are reduced up to a maximum of 50 percent.

    b. Agricultural, M&I, and exchange requests are reduced by equal percentages up to a maximum of 25 percent. At this point, cumulative agricultural deficiencies are 75 percent.

    c. Agricultural, M&I, and refuge requests are reduced by equal percentages up to a maximum of 25 percent. At this point, cumulative agricultural and M&I deficiencies are 100 percent and 50 percent, respectively.

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

    e. Further reductions are imposed equally upon exchange and refuge.

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

<u>Delta Standards</u>. The Delta objectives are maintained as required in the Bay/Delta Plan or D-1485, as applicable, except as specified below.

1. A buffer is added to insure that the M&I chloride objective at Contra Costa Canal is maintained on a daily basis. DWRSIM uses a value of 130 mg/L chloride concentration for the 150 mg/L objective and a value of 225 mg/L chloride concentration for the 250 mg/L objective.

2. Salinity and chloride water quality objectives are not modeled at the following locations: Cache Slough, Clifton Court Forebay, Tracy Pumping Plant, Mokelumne River at Terminous, Old River, western Suisun Marsh, and the San Joaquin River at San Andreas Landing, Prisoners Point, and Brandt Bridge site.

3. The San Joaquin River salinity objectives at Vernalis are maintained by releasing water from New Melones Reservoir. There is no cap on reservoir releases to meet these objectives. If

New Melones Reservoir storage drops to 80 TAF, additional water is not provided for salinity control and the objectives are violated.

4. The dissolved oxygen objective in the San Joaquin River is not modeled.

5. The Kimmerer-Monismith monthly equation, provided below, is used to calculate the outflow required to maintain the outflow/X2 objectives.

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

   In months when the X2 objective 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 objectives.

6. The relaxation of the outflow/X2 objectives that allows the transfer of excess outflow/X2 days in a single month to be credited to the next month is not modeled (see Bay/Delta Plan, Footnote "a", page 26).

7. The X2 trigger to activate the Roe Island objective is set at 66.3 km from the previous month, as an average monthly value.

B. DWRDSM

DWRDSM is a mathematical computer model that simulates the hydrodynamics and water quality in the Bay/Delta Estuary. Two versions of the model were used. The Flow Alternatives were analyzed using DWRDSM-1, which uses the Martinez tide as the downstream tidal boundary condition. The Suisun Marsh Alternatives were analyzed using DWRDSM (Suisun Marsh Version), which uses the 19-year Golden Gate mean tide as the downstream condition. Both versions use the I Street Bridge and Vernalis as the upstream boundary on the Sacramento and San Joaquin rivers respectively. The model is a variant of the Fischer Delta Model, which was developed by Hugo Fischer and is currently under the proprietorship of Flow Science Inc. DWR modified the Fischer Delta Model and created DWRDSM. DWRDSM is specifically designed to simulate salinity changes in the Delta as affected by changes in geometry and hydrology (DWR 1995).

The hydrodynamics of the Delta are described in the model by governing equations for long wave, non-uniform, unsteady flow in prismatic channels. The equations are solved numerically using the Method of Characteristics for flows, stages, and velocities at discrete locations.

The transport of dissolved water quality constituents, (total dissolved solids), is explained in the model by two distinct processes: advection and dispersion. The advection process is largely dependent on flow velocities, which are obtained by solving the hydrodynamics equations.

The dispersion process is dependent on the concentration gradient and the dispersion coefficient. The dispersion coefficients vary from one location to another and are commonly used as calibration parameters.

For the purposes of the analysis in this draft EIR, some of the boundary conditions for DWRDSM are obtained from the monthly average results from DWRSIM. In addition, the mean of the measured tidal variation over 19 years is used as a boundary condition to simulate the effects of ocean tides. DWRDSM calculates changes on a 60-second time step for flow, and a one to five minute time step for salinity. Although these time steps are relatively short, the use of monthly average flow and mean tidal variation as boundary conditions prevents the model from simulating the extremes that may result from, for example, a short-duration, high intensity storm event or a week-long period of high pumping rates.

C. DISSOLVED OXYGEN MODEL

The City of Stockton developed a model for simulating water quality, including dissolved oxygen conditions, under a variety of flow and water quality conditions (Stockton 1993). The model simulates the transport of water quality constituents, including constituents from the Stockton wastewater treatment plant outfall, in a limited segment of the San Joaquin River based on upstream inflows, Delta water withdrawals, tides, and constituent loading rates. The model includes a near-field component that simulates mixing and dilution in the immediate vicinity of the outfall and a far-field component that simulates mass transport of constituents through the river and Stockton shipping channel.

The near-field component of the model is comprised of one of the USEPA's existing plume models, UDKHDEN, which analyzes the development of the plume through the zone of flow establishment. The output parameters are plume trajectory, travel time, plume width, average dilution, and minimum dilution. UDKHDEN, like other plume models, assumes steady-state conditions. In the Stockton case, however, the currents change dynamically with the tides. Therefore, the model is applied for multiple segments of time and the results are reconstructed to provide a dynamic representation of the conditions.

The far-field component of the model is a link-node model that tracks the transport, dispersion, and decay of constituents in the river. The model encompasses the section of the San Joaquin River between Rindge Tract and McDonald Tract to the north and the confluence of the San Joaquin and Old rivers to the south. The model also includes Fourteen Mile Slough, the lower Calaveras River, the Mormon Slough, the Stockton Diverting Canal, and the French Camp Slough. The water quality parameters simulated by the model are dissolved oxygen, ammonia, biochemical oxygen demand, nitrate, total dissolved solids and coliform bacteria. The model has a hydrodynamic module and a water quality module. The hydrodynamic module generates output of tidal elevations for each node and flows for each link. The water quality module uses the output from the hydrodynamic module and performs mass balance calculations for constituents by accounting for advection, diffusion, and chemical and biological reactions. The final output is the concentrations of water quality parameters for each node on an hourly time step.

The dissolved oxygen model has been calibrated with 1991 data and verified with 1993 and 1996 data. The year 1991 was critically dry, 1993 was an above normal year, and 1996 was a wet year. Thus, the model has been shown to simulate conditions under various hydrologic year types.

A sensitivity analysis has also been performed to provide information about the effectiveness of various factors in raising dissolved oxygen concentrations. Results of the sensitivity analysis can be found in Chapter X.

D. SJRIO MODEL

SJRIO is a mass balance water quality model developed to study the effects of agricultural drainage on water quality in the San Joaquin River (SWRCB 1992, CVRWQCB 1996). Flows and concentrations of total dissolved solids (TDS), boron, and selenium are calculated for a 60 mile reach of the San Joaquin River. The upstream boundary of the model is the San Joaquin River at Lander Avenue, and the downstream boundary is near Vernalis. The following tributary river segments are also within the model boundaries:

1. Five miles of the Merced River below the United States Geological Survey (USGS) gaging station near Stevinson;

2. Fifteen miles of the Tuolumne River below the USGS gaging station at Modesto;

3. Nine miles of the Stanislaus River below the DWR gaging station at Koetitz Ranch;

4. Six miles of Salt Slough below the DWR gaging station near Stevinson;

5. Nine miles of Mud Slough below the USGS gaging station near Gustine; and

6. Several miles of three west side tributaries: Del Puerto, Orestimba and Hospital/Ingram creeks.

The San Joaquin River at Lander Avenue was chosen as the upstream boundary of the model because (1) it is downstream of Friant Dam where most of the river is diverted; (2) it is upstream of significant agricultural drainage inputs from Mud and Salt sloughs; and (3) there are substantial monitoring data available at the location. Vernalis was chosen as the downstream boundary because of data availability at this location and because it is upstream of tidal effects.

The following sources and sinks are accounted for in the model's mass balance calculations for flows and salt loads:

1. The San Joaquin River at Lander Avenue, the upstream boundary to the model;
2. The eight tributaries identified above;
3. Appropriative and riparian diversions from the San Joaquin River and the east side tributaries at 41 points;
4. Subsurface agricultural discharges at nine discharge points;
5. Surface agricultural discharges, including tail water and operational spill water at 35 sites;
6. Municipal and industrial discharges at three sites;
7. Groundwater accretions or depletions calculated for every river mile along the San Joaquin River and along the three east-side tributaries within the model study area;
8. Riparian vegetation water use for every five-mile reach of the San Joaquin River and for each of the east-side tributaries;
9. Evaporation and precipitation for every five mile reach of the San Joaquin River and for each of the east-side tributaries;

E. WATER TEMPERATURE MODEL

The water temperature model developed by the USBR (USBR 1990, 1993, 1997) was used to assess the effects of the Flow and Joint POD Alternatives on water temperature in four major streams in the Sacramento-San Joaquin River system, the Sacramento, Feather, American, and Stanislaus rivers. DWRSIM, described in Section A, was used to predict monthly project operations that were input to the temperature model for the 72-year hydrologic period of record (1922-93).

The reservoir temperature models simulate monthly mean vertical temperature profiles and release temperatures for Whiskeytown, Shasta, Oroville, Folsom, New Melones and Tulloch reservoirs based on hydrologic and climatic input data. The temperature control devices (TCD) at Shasta, Oroville, and Folsom Dams can selectively withdraw water from different reservoir levels to provide downstream temperature control. The TCDs are generally operated to conserve cold water for the summer and fall months when stream temperatures become critical for fisheries. The models simulate the TCD operations by making upper level releases in the winter and spring, mid-level releases in the late-spring and summer, and low level releases in the late-summer and fall.

Temperature changes in the downstream regulating reservoirs, Keswick, Thermalito, Natomas, and Goodwin, are computed from equilibrium temperature decay equations in the reservoir models, which are similar to the river model equations.

The river temperature models predict mean monthly water temperatures at twelve locations on the Sacramento River from Keswick Dam to Freeport, twelve locations on the Feather River from Oroville Dam to the mouth, nine locations on the American River from Nimbus Dam to the mouth, and eight locations on the Stanislaus River from Goodwin Dam to the mouth. The river temperature calculations are based on regulating reservoir release temperatures, river flows, and climatic data. Monthly mean historical air temperatures for the 72-year period and other long-term average climatic data for Shasta, Whiskeytown, Redding, Red Bluff, Colusa, Oroville, Marysville, Folsom, Sacramento, New Melones, and Stockton were obtained from Weather Bureau records and used to represent climatic conditions for the five river systems.

Assessment of impacts on aquatic resources is limited by the monthly time-step used in the DWRSIM and temperature models. Mean monthly flows and temperatures do not define daily variations that occur in the rivers due to dynamic flow and climatic conditions. These variations may have significant effects on habitat for aquatic resources. However, monthly results are useful for general comparison of the alternatives.

F. AQUATIC RESOURCE RELATIONSHIPS IN THE DELTA

The following three types of aquatic resource relationships are used in the analysis of the effects of the alternatives on aquatic resources in the Delta: (1) salmon smolt survival models, (2) estuarine outflow/abundance relationships, and (3) young-of-the-year striped bass model.

1. Salmon Smolt Survival Models

The USFWS has developed models to predict survival of juvenile chinook salmon migrating through the Delta (USFWS 1995). For the Sacramento River, models have been developed for fall-run, late fall-run, and winter-run smolts, and spring-run young-of-the-year and yearlings. For the San Joaquin River, a model has been developed for fall-run smolts.

The models are based on survival indices generated from coded-wire-tagged (CWT) fall-run hatchery smolts released at various locations in the Delta and recovered within a few weeks after release by midwater trawl at Chipps Island. Survival indices were calculated based on the number recovered at Chipps Island corrected for effort in both time and space.

Both the Sacramento and San Joaquin models split the Delta into various reaches and use backward-stepping multiple-regression analyses to identify environmental variables (exports, flows, and temperature) important to survival within each reach. Professional judgment by the model authors was used to some extent in selecting variables for consideration. Both models assume that smolts enter the various reaches of the model in proportion to flow.

The Delta smolt survival model, developed for fall-run smolts emigrating from the Sacramento River Basin, was slightly modified to better index the survival of Sacramento River juvenile winter-run, late fall-run, and spring-run chinook salmon through the Delta. The period of occurrence of each race in the Delta and associated temperature conditions were incorporated into the model.

For the Sacramento River, the models indicate that the factors with the greatest effect on smolt survival are: (1) water temperature at Freeport; (2) percent flow diverted through the Delta Cross Channel gates and Georgiana Slough; and (3) CVP and SWP exports during the migratory period. On the San Joaquin River, the corresponding primary factors are: (1) percent flow diverted into upper Old River; (2) percent flow remaining in the river at Stockton; (3) temperature at Jersey Point; and (4) CVP and SWP exports in April and May.

The model for smolt survival on the Sacramento River illustrates the importance of keeping the migrating salmon smolts on the mainstem of the Sacramento River and minimizing their diversion into the central Delta. Survival, as predicted by the model, significantly improves when the Delta Cross Channel gates are closed. The model also indicates that smolt survival is significantly affected by water temperature. Survival is very poor above a temperature of approximately 68°F regardless of other conditions.

Similarly, the model for smolt survival on the San Joaquin River illustrates the importance of keeping the migrating salmon smolts on the mainstem of the San Joaquin River and minimizing their diversion into Old River. Survival, as predicted by the model, is enhanced by operation of a barrier at the head of Old River. For those smolts that migrate down the mainstem of the San Joaquin River, factors affecting survival include flow, temperature at Jersey Point, and exports. The smolts that migrate down upper Old River and survive are assumed to have gone through the export salvage facilities and then been transported and released into the western Delta.

The models can be used to estimate the relative benefits of controllable parameters in the Delta, specifically flows, exports, Delta Cross Channel gate operation, and construction of the Old River barrier. A number of other implementation measures may also improve smolt survival, but the effects of those other measures have not been modeled.

The statistical validity of the USFWS' smolt survival model has been disputed (Kimmerer 1994). A peer review analysis facilitated by Kimmerer concluded that the models are too complex, contain too many parameters, and inappropriately convert smolt survival index values to probabilities to calculate survival through successive reaches of the Delta.

However, the USFWS salmon smolt models are not used in the analysis as quantitative management tools or to establish the outflow or export objectives. The models are used only for qualitative comparisons among the alternatives and to illustrate the factors that are believed to affect smolt survival. The models have been modified to increase their ability to predict outside the range of the original data set.

2. Estuarine Abundance/Outflow Relationships

The DFG has sampled the abundance of estuarine and bay fish species for many years. Since 1980, as part of the Interagency Ecological Program, the DFG has undertaken a specific study to investigate the relationship between Delta freshwater outflow and the abundance and distribution of fish and invertebrates. Factors other than flow can affect fish and invertebrates, but the major objective of this study was to consider outflow as it influences estuarine and bay fish resources (DFG 1987).

The abundance of 70 species of fish, shrimp, and crabs were analyzed for years since 1980. A majority of the species (55.6 percent) showed no difference in their abundance between wet and dry years. Most of the species that showed no significant difference in abundance between wet and dry years were marine. In contrast, over two-thirds of the species in the study considered to be estuarine, anadromous, or freshwater were significantly more abundant in wet years. Significant positive relationships between Delta outflow and abundance were found for four of these estuarine species: a bay shrimp, *Crangon franciscorum*; longfin smelt; starry flounder; and Sacramento splittail (DFG 1987, 1992a).

In addition to these outflow/abundance relationships, Jassby developed relationships between X2 and several aquatic resources in the Estuary, including: particulate organic carbon (POC), a small mysid shrimp, *Neomysis mercedis, C. franciscorum*, starry flounder, longfin smelt, striped bass, and mollusks (SFEP 1992). These aquatic resources were selected because they were found by the DFG to be affected by outflow, and because they are representative of various trophic levels in the Estuary. The regression equations for six of these estuarine resources/species (POC, *Neomysis mercedis, C. franciscorum*, longfin smelt, starry flounder, and Sacramento splittail), and the data used to develop the equations are plotted in the ER to the Bay/Delta Plan (Chapter VI, pages VI-8, VI-9, and VI-11).

In recent years, there is evidence that a number of these relationships have weakened since the introduction of the Asian clam, Potamocorbula (Kimmerer 1997a). In addition, recent work by Sommer et al (1997) suggests that Sacramento splittail abundance is more closely associated with floodplain inundation from February through May than Delta outflow.

In spite of these drawbacks, the outflow/abundance relationships for some species remain significant and were considered adequate tools to evaluate the relative effects of the alternatives on abundance of these species. Current outflow/abundance relationships (revised in 1998) are used in Chapters VI and XIII to evaluate effects of the Flow and Joint POD alternatives on *C. franciscorum*, longfin smelt, starry flounder, and Sacramento splittail.

3. Young-of-the-Year Striped Bass Model

The DFG has sampled the abundance of young-of-the-year striped bass in the Bay/Delta system using standardized methods since 1959. Analysis developed by DFG in the 1970's showed significant positive relationships between young-of-the-year abundance at 38 mm. and Delta outflow and exports (Turner and Chadwick 1972; Chadwick et al. 1977). Although these relationships have weakened in recent years, a significant positive relationship still exists between young-of-the-year striped bass abundance from 1959 through 1998 and Delta outflow and export variables.

A multiple regression recently developed by DFG relating total young-of-the-year striped bass abundance at 38 mm. to the mean April – July San Joaquin River flow past Jersey Point, $\log_{10}$ net Delta outflow, and total Delta exports (including CVP, SWP, Contra Costa Canal, and miscellaneous Delta diversions) (Lee Miller, DFG, personal communication) was used to evaluate effects of the alternatives on striped bass. Young-of-the-year indices for 1959 – 1998 were correlated with April - July flow data from DWR DAYFLOW. This relationship was used to predict the effects of the Flow, Joint POD, and Cumulative Impacts Alternatives on young-of-the-year striped bass abundance. The DWRSIM model was used to simulate flows for the project alternatives over the 1922-1994 period of hydrologic record.

The abundance of adult striped bass was not modeled for the following reasons: 1) recent literature indicates that many factors other than those included in existing adult striped bass models affect the size of the adult striped bass population (Bennett and Howard 1997; Kimmerer 1997b), and 2) the alternatives under consideration will primarily affect the young-of-the-year life stage through changes in Delta outflow and exports.

G. WATER RIGHT PRIORITY ANALYSIS

This section describes the calculations used to allocate responsibility to meet the flow objectives based on the water right priority system (Flow Alternatives 3 and 4). The discussion is in two parts: (1) calculation of water subject to allocation and (2) calculation of stream depletions due to diversions.

1. Calculation of Water Subject to Allocation

The beginning point of the water right priority calculation is the recognition that the watershed protection statutes (Water Code §§ 11460 et seq. and §§ 15505 et seq.) assign the SWP and the CVP export projects the most junior priority in the Central Valley. The export projects are assumed to include both the export pumps and the reservoirs that release water for diversion at the export pumps. Therefore, both direct diversions to the export pumps and storage in a reservoir that provides water to the export pumps are treated in the calculations as having a priority junior to all other diversions in the basin. This junior priority extends only to the natural and abandoned flow in the system. This junior priority does not apply to SWP and CVP storage releases or their imports into the basin. Consequently, the SWP and the CVP export projects must bypass all of the inflow to their reservoirs plus either release from storage or import into the basin sufficient water to meet their export demands before any other party is required to curtail diversion.

For purposes of a water right priority analysis, the flow objectives for the San Joaquin River at Vernalis are treated separately from the Delta outflow objectives. This segregation is necessary because only San Joaquin Basin water right holders are responsible for the Vernalis objectives, but all water right holders in the Sacramento and San Joaquin basins are responsible for the Delta outflow objectives. In addition, because there are two water right priority flow alternatives, one in which the Friant Project is treated as an in-basin project and entitled to watershed of origin protections (Flow Alternative 3) and one in which it is treated as an export project (Flow Alternative 4), there are a total of four sets of calculations: (a) Vernalis calculation for Flow Alternative 3; (b) Delta calculation for Flow Alternative 3; (c) Vernalis calculation for Flow Alternative 4; and (d) Delta calculation for Flow Alternative 4.

a. Vernalis Calculation for Flow Alternative 3. The watershed protection statutes do not apply to this calculation because the Friant Project is treated as an inbasin project, and there is, therefore, no SWP or CVP export project in the San Joaquin Basin. The quantity of water in excess of natural and abandoned flow needed to meet the Vernalis flow objectives can be obtained from the DWRSIM output files. The model calculates the quantity of releases from New Melones Reservoir, New Don Pedro Reservoir, and Lake McClure required for this purpose, and specific model output files identify this quantity of water. This quantity of water is provided by curtailing diversions of water right holders in the San Joaquin Basin water right holder database in order of water right priority. Water is available from a water right holder to meet the Vernalis objectives if the water right holder is directly diverting water or diverting water to storage in the months in which flows are required. Monthly average diversions to storage are available from the DWRSIM output files. The calculation of monthly average direct diversion quantities is described in the next section of this report.

In real-time operation of this alternative, an estimate would be made of the near-term flow deficiency in the San Joaquin River, and the appropriate number of water right holders would be directed to curtail diversions.

b. Delta Calculation for Flow Alternative 3. The watershed protection statutes apply to this calculation. The SWRCB includes Standard Term 91 in all permits issued since 1965 to ensure that inbasin users are not diverting water that is released from storage by the DWR and the USBR to meet Delta objectives. The method for calculating the responsibility of other users to provide water for Delta objectives is based on a modified Term 91 approach. Term 91 states:

> No diversion is authorized by this permit when satisfaction of inbasin entitlements require release of supplemental project water by the SWP and the CVP.

a. Inbasin entitlements are defined as rights to divert water from streams tributary to the Delta for use within the respective basins of origin or the legal Delta, natural requirements for riparian habitat and conveyance losses, and flows required by the SWRCB for maintenance of water quality and fish and wildlife. Export diversions and project carriage water are specifically excluded from the definition of inbasin entitlement.

b. Supplemental project water is defined as water imported to the basin by the projects and water released from project storage which is in excess of export diversions, project carriage water, and project inbasin deliveries.

As shown in Figure IV-1, the Term 91 method treats the Delta watershed as if it is a fully interconnected basin below the foothill reservoirs. Water availability is assumed to be the same throughout the basin. When natural and abandoned flow in the basin is greater than the inbasin demand plus Delta outflow requirements, water is available for appropriation. When natural and abandoned flows are insufficient to supply inbasin needs and Delta outflow requirements, the SWP and the CVP must release stored water, under the present regulatory requirements, to ensure that inbasin entitlements are met.

Term 91, as presently applied, can be expressed in the following mathematical notation, and an example of a Term 91 calculation is provided in Figure IV-1.

$$SW = SR - (EX + CW)$$

Where:
- SW => Supplemental water, as defined above.
- SR => Project storage releases from Shasta, Oroville and Folsom reservoirs, plus imports from the Trinity River.
- EX => Export diversions into the California Aqueduct, the Delta-Mendota Canal, the Contra Costa Canal, and the North Bay Aqueduct.
- CW => Carriage water required to repel seawater due to operation of the export pumps.

This method of calculating supplemental water was approved by the SWRCB in Order 81-15. The order states that carriage water does not apply when a flow objective is the controlling objective in the Delta. Under D-1485, salinity objectives controlled the majority of the time, and carriage water was an important consideration. However, under the 1995 Bay/Delta Plan, outflow objectives control the majority of the time. Therefore, the carriage water term is almost always zero, and it can be ignored in the Term 91 calculation at this time. In addition, the version of DWRSIM used in the modeling study for this draft EIR does not include a carriage water calculation and so the information is not available for purposes of calculation in the draft EIR.

Figure IV-1 Term 91

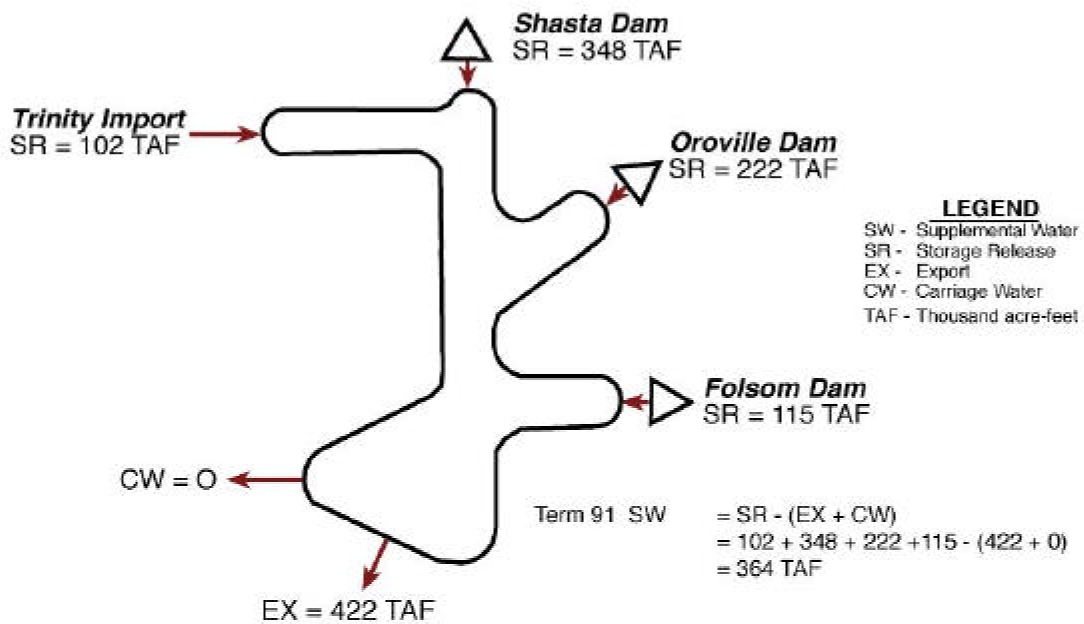
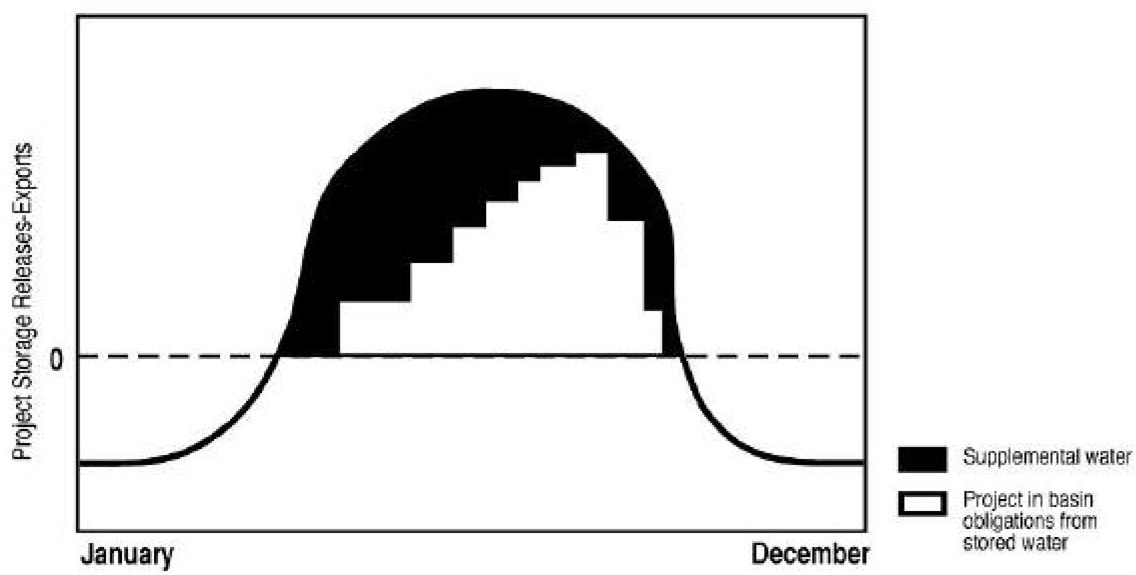


Figure IV-2. Graphical Representation of Supplemental Water Calculations



Although Term 91 recognizes the projects' obligation for inbasin deliveries, the equation above does not include a term for this obligation. This is because Term 91 presently is included only in appropriative water rights issued after 1965, and those rights are junior to the inbasin rights of the SWP and the CVP. Before the equation used to calculate supplemental water can be applied to all post-1914 appropriators on the data base, the equation must be modified to account for the projects' obligation to serve their inbasin contractors with stored water. For contractors with no independent water rights and contractors with water rights junior to the projects, the obligation exists when the contractors are being served with water under the projects' rights, and the projects' inbasin direct diversions have been curtailed. For contractors with water rights senior in priority to the projects, the obligation exists when the contractors' rights to divert water have been curtailed. The new term that must be added to the Term 91 equation tracks this inbasin obligation (IO) that requires the release of stored water. As direct diversions under the projects' inbasin rights are curtailed and as direct diversions of contractors with rights senior to the projects are curtailed, the storage release obligations of the projects increase in an amount adequate to serve these contractors. These increased storage release obligations are project obligations and not the responsibility of inbasin users and must be subtracted from the projects’ storage release when supplemental project water is calculated. This situation is illustrated in Figure IV-2.

The new equation that can be used to implement a Term 91 approach for all post-1914 appropriators is defined below.

$$SW_3 = SR - (EX + IO_n)$$

In real-time operation, water right holders would be required to curtail diversions to ensure that supplemental water does not exceed zero. In the context of the model results, DWRSIM output files can be used to calculate the number of water right holders that would be required to curtail diversion by using the following equation:

$$SR - (EX + IO_n) = DD_n + Sto_n$$

Where:
- SW_3 => Supplemental water for Flow Alternative 3.
- IO_n => Project inbasin obligations at water right priority (n) that require the release of stored water.
- DD_n => Reduction in stream depletions from cessation of direct diversions at water right priority (n).
- Sto_n => Reduction in stream depletion from cessation of storage at water right priority (n).

For purposes of calculation, it is convenient to express the equation in the following form:

$$SR - EX = DD_n + Sto_n + IO_n$$

The quantity on the left side of the equation identifies the amount of water that is needed to satisfy inbasin entitlements after the obligations of the SWP and the CVP due to their export operations have been met. Another way to think of this term is that it is the quantity of water being used by inbasin water users beyond their inbasin rights. The terms on the right side of the equation identify the inbasin sources available to satisfy the inbasin entitlements.

The DWRSIM output provides the quantities SR, EX, and Sto_n on a monthly average basis, and monthly average estimates of IO_n and DD_n can be calculated, as described in the next section of this report. The number of direct diversions and diversions to storage that need to be curtailed can also be calculated on a real-time basis using this equation. The quantities SR, EX, and Sto_n can be obtained on a daily basis from the SWP and the CVP and from non-project reservoirs subject to curtailment of diversions to storage, and daily estimates of IO_n and DD_n can be calculated.

For ease of analysis of an alternative of this nature, water right holders in the database subject to this alternative have been placed into one of eight groups based on their water right priority. All of the water right holders in a group would be directed to curtail diversions at the same time. A group is not directed to curtail diversions unless there is no water available to the entire group. However, the SWRCB could direct that water right holders be treated individually and not placed into water right priority groups.

c. <u>Vernalis Calculation for Flow Alternative 4</u>. The watershed protection statutes apply to this calculation because the Friant Project is treated as an export project. The alternative further assumes that the Friant Project's obligations will be met by releases from New Melones Reservoir.

A principal issue in the analysis of this alternative is the treatment of the Exchange Contractors. These contractors have retained their riparian and pre-1914 appropriative water rights on the upper San Joaquin River, but they executed a contract with the CVP to receive water from any source, including the Delta, in exchange for their San Joaquin River water. This exchange allows the diversion of the majority of the San Joaquin River at Friant Dam for use in the Tulare Lake Basin. This routing of water is more efficient than the alternative of supplying the Friant-Kern service area with water diverted from the Delta. From a water right perspective, deliveries to the Exchange Contractors can be treated as inbasin deliveries because the contractors have inbasin rights. The conceptual model for the calculation is a water routing system in which (1) San Joaquin River water is provided to the Exchange Contractors; (2) unmet demands of the Exchange Contractors are met with diversions from the Delta; (3) any remaining water from Millerton Lake after the inbasin demands are met is exported to the Friant-Kern service area; and (4) remaining export demands in the Friant-Kern service area are met with diversions from the Delta.

The following additional assumptions are made to calculate responsibility to achieve the Vernalis flow objectives under this alternative.

1. Friant-Kern exports are defined, for the purposes of application of the watershed protection statutes, as total diversions into the Friant-Kern Canal minus deliveries to the Kings River Basin. This definition is based on the statutes, which provide protection both to the watershed of origin and to immediately adjacent areas that can be conveniently served from the watershed of origin. The Kings River Basin is assumed to be an immediately adjacent area that can be conveniently served from the San Joaquin River.

2. Exchange contractor deliveries are obtained from the DWRSIM output files. In order to determine the inbasin deliveries, the output files are capped based on two other considerations. First, the deliveries cannot exceed the contractual amount of 840 TAF. Second, the deliveries cannot exceed the amount of water that would be available under the contractors' water rights if they were diverting from the San Joaquin River. This quantity is obtained by subtracting riparian diversions between Millerton Lake and Gravelly Ford from the inflow to Millerton Lake.

3. Exchange contractor monthly deliveries, as defined in (2) above, are subtracted from Friant-Kern monthly exports, as defined in (1) above, to obtain the final Friant-Kern export term used for subsequent calculations. If the exchange contractors' deliveries are greater than exports, the Friant-Kern export term is set to zero.

Using the assumptions and conceptual model described above and DWRSIM output files, the responsibility of water right holders other than the CVP to release water to meet the Vernalis objectives can be calculated using the following equation:

$$SW_{SJ} = Add + SR_F - (EX_F + IO_{Fn})$$

Where: SW_{SJ}	=>	Supplemental water for the Vernalis objective - the quantity of water that water users, other than the Friant Project, are required to bypass to meet the Vernalis flow objectives (negative numbers are set to zero and SW_{SJ} # Add).
Add	=>	The quantity of water above natural and abandoned flows in the San Joaquin River needed to achieve the Vernalis flow objectives.
SR_F	=>	Millerton Lake storage releases.
EX_F	=>	Friant-Kern exports, as defined above
IO_{Fn}	=>	Friant Project inbasin obligations that would require the release of stored water at water right priority (n) because of the Vernalis objective.

The number of direct diversions and diversions to storage in the San Joaquin River that need to be curtailed to achieve the quantity SW_{SJ} is determined using the method described in the previous section. Specifically, the following equation is used.

$$Add + SR_F - (EX_F + IO_{Fn}) = DD_n + Sto_n$$

In this equation, the terms DD_n and Sto_n represent the reductions in stream depletions in the San Joaquin Basin from cessation of direct diversions and storage, respectively, of water users in the basin at water right priority (n).

For purposes of calculation, it is convenient to express the equation in the following form.

$$Add + SR_F - EX_F = DD_n + Sto_n + IO_{Fn}$$

The quantity on the left side of the equation identifies the amount of water that is needed to satisfy inbasin entitlements in the San Joaquin Basin after the obligations of the Friant Project due to its export operations have been met. (When SR > or = to EX, the left side of the equation is set equal to Add.) Alternatively, the term can be thought of as the amount of water being used by inbasin water users beyond their inbasin water rights. The terms on the right side of the equation identify the inbasin sources in the San Joaquin Basin available to satisfy the inbasin entitlements.

The Friant Project's share of the Vernalis flow objectives (FO) can be calculated using the following equation. New Melones Reservoir is responsible for releasing this quantity of water.

$$FO = Add - SW_{SJ}$$

All of the terms described above can be either calculated or extracted from the DWRSIM output. In real-time operation, the terms of the equations can be determined on a daily basis from monitoring data or they can be calculated, as described in the sections above.

d. Delta Calculation for Flow Alternative 4. The only difference between the calculation for this alternative and the calculation for the responsibility to achieve the Delta objectives under Flow Alternative 3 is that the Friant Project has been added as an export project. Consequently, the following equation applies:

$$SW_4 = SW_3 + SR_F - (EX_F + IO_{Fn}) + FO$$

Where: SW_4 => Supplemental water for Flow Alternative 4

For purposes of calculation, it is convenient, for the reasons described in the previous two sections, to express the equation in the following form.

$$SR - EX + FO = DD_n + Sto_n + IO_n$$

In this equation, the terms SR, EX, and IO_n apply to all of the export-related operations of the projects in the Sacramento and San Joaquin basins, including the operations of the Friant Project.

The quantity on the left side of the equation identifies the amount of water that is needed to satisfy inbasin entitlements after the obligations of the SWP and the CVP due to their export operations have been met. The terms on the right side of the equation identify the inbasin sources throughout the Sacramento and San Joaquin basins available to satisfy the inbasin entitlements.

2. Calculation of Stream Depletions Due to Diversions

Most of the terms in the equations described in the previous section are obtained from DWRSIM output files. However, two of the terms, DD and IO, are calculated. A description of how these terms are calculated is provided below.

a. **DD Calculation**. The DD term provides the depletions due to direct diversions of water right holders without a contract with the SWP and the CVP. The term is calculated by multiplying the irrigated acreage of the water right holder both by the monthly consumptive use of applied water (CUAW) factor for the depletion study area (DSA) in which the depletion occurs and by a nonrecoverable losses factor. The irrigated acreage data is obtained from Reports of Permittee and Licensee in the SWRCB files. The monthly CUAW factor for each DSA is available from DWR and is based on land use studies conducted by the DWR. The nonrecoverable losses factors were obtained from the DWR. The factor is ten percent for diversions on the valley floor and fifteen percent for diversions in the rim areas. For applicants with multiple rights, diversions are assumed to occur first under the senior right until the full face value of the right is exhausted. When multiple rights have overlapping places of use, the acreage applied to each right is determined on a case-by-case basis by reviewing detailed place of use maps. Volume 2, Appendix 3 contains tables that identify the magnitude of the DD term at the different water right priorities.

b. **IO Calculation**. The projects' inbasin contractors fall into one of two categories: water supply contractors and water settlement contractors. Water supply contractors divert under the projects' rights and make full payment for water received. Water settlement contractors have their own water rights, and they divert under those rights until water is no longer available under their priority, at which time they divert under the projects' rights. The CVP settlement contracts specify monthly quantities of water available under the contractors' water rights (base supply). Amounts of water used in excess of the base supply are considered the CVP's supply for which payment is required.

The projects have inbasin direct diversion water rights that they use to provide service to their contractors. When water is no longer available under these direct diversion water rights, depletions due to the contractors diverting under these rights must be met by releases from the projects' storage. Some settlement contractors have rights to divert water at priorities senior to the projects' inbasin rights. When these contractors rights are curtailed, their depletions also become a storage release obligation of the projects. The IO term provides the depletions due to diversions of the projects' contractors when the contractors are no longer able to divert under their own rights, if any.

The IO term is calculated by multiplying monthly average deliveries to each contractor by the basin efficiency and a non-recoverable loss factor. The monthly average deliveries are derived by distributing the average annual deliveries for the period 1982 through 1989 (excluding 1983 which was an exceptionally wet year), which were provided by the projects, among the months of the irrigation season based on the delivery pattern to the Tehama-Colusa Canal. The basin efficiency and the non-recoverable loss factor were obtained from the DWR.

The IO term for a specific contractor may be reduced in years when deficiencies are imposed on inbasin project deliveries. Deficiencies are calculated as a percentage of base and project entitlement. Deficiencies are applied first to project water contractors up to a maximum of 50 percent of entitlement, then to settlement contractors up to 25 percent of combined project and base supply. A preliminary IO term under deficiency conditions is calculated for each contractor based on the assumptions described above. This quantity is then compared to the IO term under normal conditions, which is based on depletions caused by average deliveries. The smaller of the terms is used as the final IO term under deficiency conditions. Volume 2, Appendix 3 contains tables of the possible combinations of IO terms used in the calculations.

H. WATERSHED ANALYSIS

Flow Alternative 5 establishes flow requirements to meet Vernalis and Delta outflow objectives for individual watersheds tributary to the Delta based upon their relative contribution to unimpaired Delta inflow. Data for unimpaired flow were obtained from DWR and is published in a document titled California Central Valley Unimpaired Flow Data – 1920-1992 (DWR 1994c). For each basin, a minimum monthly flow obligation is calculated for each of the five water year types defined in the 1995 Bay/Delta Plan. The individual tributary flow requirements are listed in Table II-7. The responsibility to meet requirements is assigned to the rim reservoirs that control downstream flow. In addition, upstream reservoir owners with cumulative capacity of greater than 100 TAF would also share responsibility. The affected reservoirs are listed in Table II-8. If more than one party has an obligation on a given tributary, the responsibility is divided among parties based on each party's depletion of the tributary. The responsibility on rivers controlled by the SWP or the CVP is assigned entirely to the projects, as is overall responsibility for meeting the Delta outflow objectives.

1. Calculation of Watershed Allocation

Average required monthly flows are calculated for each watershed and each water-year type. In the calculation, the Sacramento and San Joaquin basins are treated differently, depending on the month. Tributaries to the San Joaquin River upstream of Vernalis contribute to both the Vernalis and the Delta outflow objectives during the months of February through June and in October. In the Sacramento basin and for the East Side Streams, tributaries contribute only to Delta outflow. Consumptive use within the Delta, which is assumed to be entirely riparian, is assigned to the Sacramento basin tributaries. Also, for the purposes of this analysis, Putah and Cache creeks are assigned no obligation to Delta outflow.

Tributary obligations are calculated using the following equations:

For months with Vernalis objectives:

SR Tribs = (SR %) x (Adjusted Average Minimum Delta outflow) + (SR %) x (Average Delta CU)

SJR Tribs = (SJR %) x (Avg. SJR flow objective)

Where:

CU	=>	Consumptive Use
SR	=>	Sacramento River
SJR	=>	San Joaquin River
SR %	=>	the average unimpaired contributions of the Sacramento River expressed as a percent of the total contribution of tributaries participating in the basin
SJR %	=>	the average unimpaired contributions of the San Joaquin River expressed as a percent of the total contribution of tributaries participating in the basin

The Average Minimum Delta Outflow, San Joaquin River Objective, and Delta Consumptive Use data are taken directly from a DWRSIM study in which all 1995 Bay/Delta Plan objectives are met by the projects and other sources as needed. The adjusted minimum Delta outflow for each water year type is equal to the minimum required Delta outflow minus the required San Joaquin River flow. Tables showing the details of the calculation are in Volume 2, Appendix 4.

In months without Vernalis objectives:

SR Tribs = (Overall %) x (Adj. Avg. Min. Delta outflow) + (SR %) x (Avg. Delta CU)
SJR Tribs = (Overall %) x (Adj. Avg. Min. Delta outflow)

In watersheds with multiple major parties, a cost sharing formula was devised based on each party's depletion of water from the tributary. Exported water creates no return flow. Therefore, for the districts that export water, depletions are equal to total diversion. Table IV-1 specifies the diversion, depletion, and percent of the total depletion for the Yuba, Bear, and Tuolumne Rivers. The responsibility of each party to meet the flow obligation for its tributary is equal to the percent total depletion for the tributary.

Table IV-1
Flow Alternative 5 Obligations for the Yuba, Bear, and Tuolumne Rivers

Agency	Average Diversion (afa)	Average Depletion (afa)	Total Depletion (%)
Yuba River Obligations[1]			
Yuba Co Water Agency	232,470	166,472	24.83
PG&E	381,808	381,808	56.95
Nevada I.D.	58,600	58,600	8.74
Oroville Wyandotte I.D.	63,538	63,538	9.48
Bear River Obligations[2]			
Nevada I.D.	52,201	37,381	34.90
South Sutter W.D.	82,350	61,651	57.55
Camp Far West I.D.	10,803	8,088	7.55
Tuolumne River Obligations[3]			
City of San Francisco	240,258	240,258	21.1
Modesto I.D.	264,812	235,074	20.6
Turlock I.D.	749,138	665,010	58.3

1. Data Source: April 30, 1997 letter from Bookman Edmonston
2. Data Source: SWRCB files for A2652A and A14804
3. Data Source: SWRCB files

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