APPENDIX I

SURFACE WATER HYDROLOGY

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INTRODUCTION

CALVIN models California's inter-connected water supply system. In Northern California, this consists of all inflows to the Central Valley originating from the Trinity-Cascade, Sierra Nevada and Coastal Mountain ranges. It also includes many small streams that result from direct runoff within the Valley floor. Much of Southern California is arid or semi-arid and is dependent on imports from the Central Valley, Owens Valley and the Colorado River for majority of its water supply. Local surface water supplies are available only in the South Coast Hydrologic Region, where coastal range streams represent approximately six percent of supply (DWR 1994, Vol. II, p103).

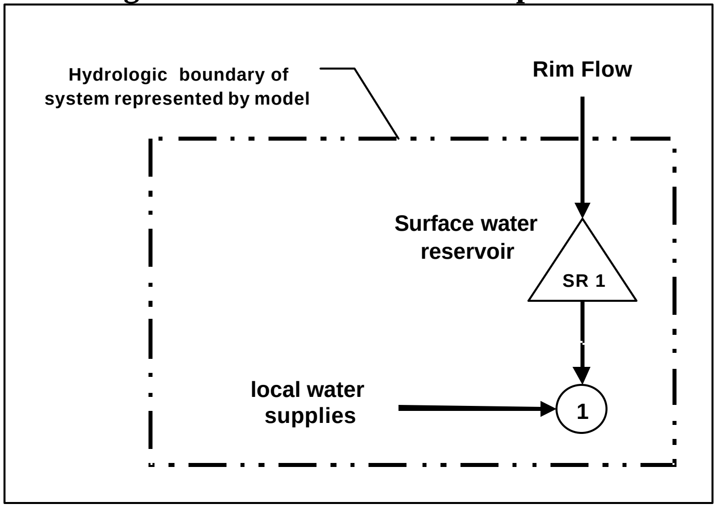
CALVIN represents surface water supplies as a time series of monthly inflows. In HEC-PRM terminology, these inputs are referred to as "external flows", and represent an inflow from the "super source" to a model node USACE (1999). The external flows can be divided into two categories:

- ☐ Rim flows; and
- ☐ Local water supplies.

Rim flows represent streams that cross the boundary of the physical system being modeled. Typically they represent inflows to surface water reservoirs located in either the Sierra Nevada foothills or the Trinity/Cascade Mountain range. Local water supplies represent surface water that originates within the boundary of the region being modeled, either from direct runoff or through surface water-groundwater interaction. In some models, these local water supplies are called gains or accretions and depletions. The distinction between rim flows and local water supplies is made as two different sources of data have been used for estimating external flows in the Central Valley: one for rim flows, the other for local water supplies.

Hydrologic data for CALVIN have been extracted from other large-scale computer models that are in the public domain. Additional data have been derived from DWR's depletion analysis, USGS and USACE stream gages, and DWR's unimpaired hydrology. This appendix describes briefly the different models from which data have been drawn, followed by a more detailed description of the external flows represented in CALVIN and how they were obtained. This detailed description of external flows is broken down by hydrologic region to allow comparison with DWR's Bulletin 160-98 water supply estimates.

Figure I-1. Surface Water Components



CALVIN is an implicitly stochastic optimization model. It prescribes monthly system operation based on a time series of monthly inflows. CALVIN is also a static model with a year 2020 planning horizon. Demand is estimated from a static agricultural production model and a static urban demand model. Results, in particular deliveries, should therefore be interpreted in terms of supply reliability, rather than indicating any particular sequence of flows. The input hydrology is based on the historic hydrologic record. The selected 72-year period October 1921-September 1993 was chosen due to the ready availability of data prepared for State and Federal simulation models. This period also represents the extremes of California's weather. Included in the time period are the three most severe droughts on record: 1928-1934, 1976-1977, and 1987-1992 (DWR 1998, Vol. 1, p3-6).

The historic time series of streamflows must be adjusted to reflect 2020 conditions. Flows are modified to account for:

- ☐ Changes in land use affecting the amount and timing of direct runoff;
- ☐ Changes in land use affecting consumptive use through evapotranspiration;
- ☐ Construction of new storage facilities;
- ☐ Changes in the projected operation of existing storage facilities; and
- ☐ Changes in regional imports and exports.

The hydrology is determined by assuming a fixed 2020 cropped acreage.[1]

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[1] Allocation of water by CALVIN to the agricultural sector is based on value functions determined by SWAP, an agricultural production model. SWAP assumes that farmers will change their allocation of land and capital in response to the available water. Annual variation in deliveries prescribed by CALVIN implies changes in cropped area and/or cropping pattern. However, the hydrology is not readjusted due to differences between the assumed land use and CALVIN's prescription. This limitation is discussed in more detail under the description of CVGSM.

CALIFORNIA REGIONS

DWR Planning Regions

For planning purposes, the DWR divides the state into:

- ☐ Hydrologic Regions (HR);
- ☐ Planning Sub-Areas (PSA); and
- ☐ Detailed Analysis Units (DAU).

The three categories represent different levels of resolution. The hydrologic region is the largest planning unit. California has ten hydrologic regions corresponding to the state's major drainage basins. These are shown in Figure I-2. Table I-1 compares the rainfall and runoff for each region. The PSA is a smaller planning unit. Their relationship to the hydrologic regions is shown in Figure I-3. In total, the state is divided into 42 PSAs. The DAU is the smallest unit of area used by DWR for planning purposes. The DAus are generally defined by hydrologic features or boundaries of water service areas. In agricultural areas, a DAU is typically 100,000 to 300,000 acres. There are a total of 278 DAUs. PSAs are an aggregation of DAUs. The Hydrologic Regions consist of one to eight PSAs.

Water supply estimates DWR's Bulletin 160 series starts at the DAU level. Results are aggregated into hydrologic regions for presentation.

Table I-1. Hydrologic Regions

Hydrologic Region	Average Annual Precipitation	Average Annual Runoff	Area
	(in)	(taf)	(sq. miles)
North Coast	53.0	28,886	19,590
Central Coast	20.0	2,477	11,280
South Coast	18.5	1,227	10,950
San Francisco Bay	31.0	1,246	4,400
Sacramento River	36.0	22,390	26,960
San Joaquin River	13.0	7,933	15,950
Tulare Basin	14.0	3,314	16,520
North Lahontan	32.0	1,842	3,890
South Lahontan	8.0	1,334	29,020
Colorado River	5.5	179	19,730

Source: DWR 1998

Detailed Study Areas

In order to develop input hydrology for the Department of Water Resources SIMulation model, DWRSIM, the Division of Planning has developed a set of 'depletion study areas' that divide the Sacramento and San Joaquin Valleys into 37 regions. The boundaries were chosen to facilitate the calculation of a water balance. Typically, the delineation follows drainage lines and watershed boundaries in the Sierras and Coastal foothills and a combination of drainage and water service areas within the Valley floor. The lowest elevation of the principal stream in a depletion area is called the "outflow point." These points usually correspond to the location of stream gages where the historic flow is known. Table I-2 lists the depletion study areas (also

Table I-2. DWR Depletion Areas

Areas	Point of Outflow	Upstream Areas
Upper Sacramento River Basin		
61	Pit River above Fall River	None
62	Sacramento River at Shasta Reservoir	61
3	Paynes Creek Group	None
58	Sacramento River at Red Bluff	62, 3
5	Thomes and Elder Creek	None
66	Northeast tributaries: Antelope, Mill, Deer and Big Chico	None
10	Sacramento River at Ord Ferry	58, 5 and 66
15	Sacramento River at Knights Landing	10
12	Sacramento Valley Westside above Colusa Basin Drain	None
Feather River		
17	Feather River at Oroville	None
14	Butte and Big Chico Creeks	None
67	Upper Yuba River including Deer and Dry Creeks	None
68	Bear River at Camp Far West	None
69	Lower Feather to mouth	None
Lower Sacramento River Basin		
22	American River at Folsom Reservoir	None
70	Lower Sacramento River to the Delta	12, 15, 69, 68
Cache, Putah and Yolo Bypass		
16	Cache Creek above Rumsey	None
24	Putah Creek near Winters	None
65	Yolo Bypass and Westside minor streams inflow to the	16, 24
Delta Eastside Streams		
25	Cosumnes above Michigan Bar	None
27	Dry Creek at Galt	None
29	Mokelumne above Camanche Reservoir	None
32	Calaveras above Jenny Lind	None
59	Eastside Streams to the Delta	25,27, 29, 32
Delta Westside Tributaries		
51	Westside minor streams inflow to the Delta	None
San Joaquin River		
39	Stanislaus River at Melones Reservoir	None
40	Tuolomne River above La Grange Dam	None
41	Merced River at Exchequer	None
42	Bear Creek Group	None
43	Chowchilla River above Buchanan Dam	None
44	Berenda Creek	None
45	Fresno River	None
46	San Joaquin at Friant	None
49	San Joaquin river at Vernalis	39, 40, 41, 42, 43, 44,
Delta		
54	Delta Lowlands	55
55	Delta Uplands	49, 51, 59, 65, 70
Note: The term “Group” indicates that in addition to the named creek there is unmeasured local runoff.		

Source: Table 2, Summary of hydrologies at the 1990, 1995, 2000, 2010 and 2020 levels of development for use in DWRSIM planning studies. Memorandum Report, DWR, July 1994.

known as depletion areas or DAs). Their relationship to the DAUs is shown in Figure I-4. DA 60 corresponds to the Tulare Basin. DWR has not developed a hydrology for this region.

CVPM Regions

CALVIN uses DWR's subdivision of the Central Valley into DAs to identify modeling units of agricultural production. In the northern part of the Central Valley, nine DAs are used to represent model units 1 through 9 that cover the Sacramento Valley and the Delta. To the south of the Delta, the Valley floor is divided into just two DAs representing the San Joaquin (DA 49) and the Tulare Lake Basin (DA 60). This is insufficient resolution for the agricultural production model. Following the approach taken by the CVPIA Draft Programmatic Impact Statement (USBR 1997), these two DAs have been split into 12 sub-areas. The resulting model regions are shown in Figure I-5. Table I-3 gives the correspondence between the 21 CVPM regions and the Depletion Study Areas. However, it should be noted that the DAs are not always an aggregation of DAUs.

Table I-3. DA and CVPM Regions

DA	CVPM	DA	CVPM
58	1	49C	12
10	2	49D	13
12	3	60A	14
15	4	60B	15
69	5	60C	16
65	6	60D	17
70	7	60E	18
59	8	60F	19
55	9	60G	20
49A	10	60H	21
49B	11		

DWR's land use data are determined at the level of DAU. In order to use these data, DAUs have been assigned to each CVPM region as shown in Table I-4.

Southern California Regions

Four model regions are used to represent agricultural land in Southern California. The model regions follow either PSA or DAU boundaries. Three of the four are located in the Colorado River Hydrologic Region: Imperial Valley PSA, Coachella Valley PSA, and Colorado River PSA. The fourth model unit is San Diego County, DAU 120.

Table I-4. DAU and CVPM Regions

Region	DAU
CVPM 1	137, 141, 143, 145
CVPM 2	142, 144
CVPM 3	163
CVPM 4	164, 165, 167
CVPM 5	159, 160, 166, 168, 170, 171
CVPM 6	162, 191, part of 41
CVPM 7	161, 172
CVPM 8	173, 180, 181, 182, 184
CVPM 9	185, 186
CVPM 10	216
CVPM 11	205, 206, 207
CVPM 12	208, 209
CVPM 13	210, 211, 212, 213, 214, 215
CVPM 14	244, 245
CVPM 15	235, 237, 238, 241, 246
CVPM 16	233, 234
CVPM 17	236, 239, 240
CVPM 18	242, 243
CVPM 19	255, 259, 260
CVPM 20	256, 257
CVPM 21	254, 258, 261

Notes: For DAU 41, only the Solano County portion is included. Napa County is excluded.

Figure I-2
California Counties and Hydrologic Regions

Figure I-3
Hydrologic Regions and Planning Sub-Areas

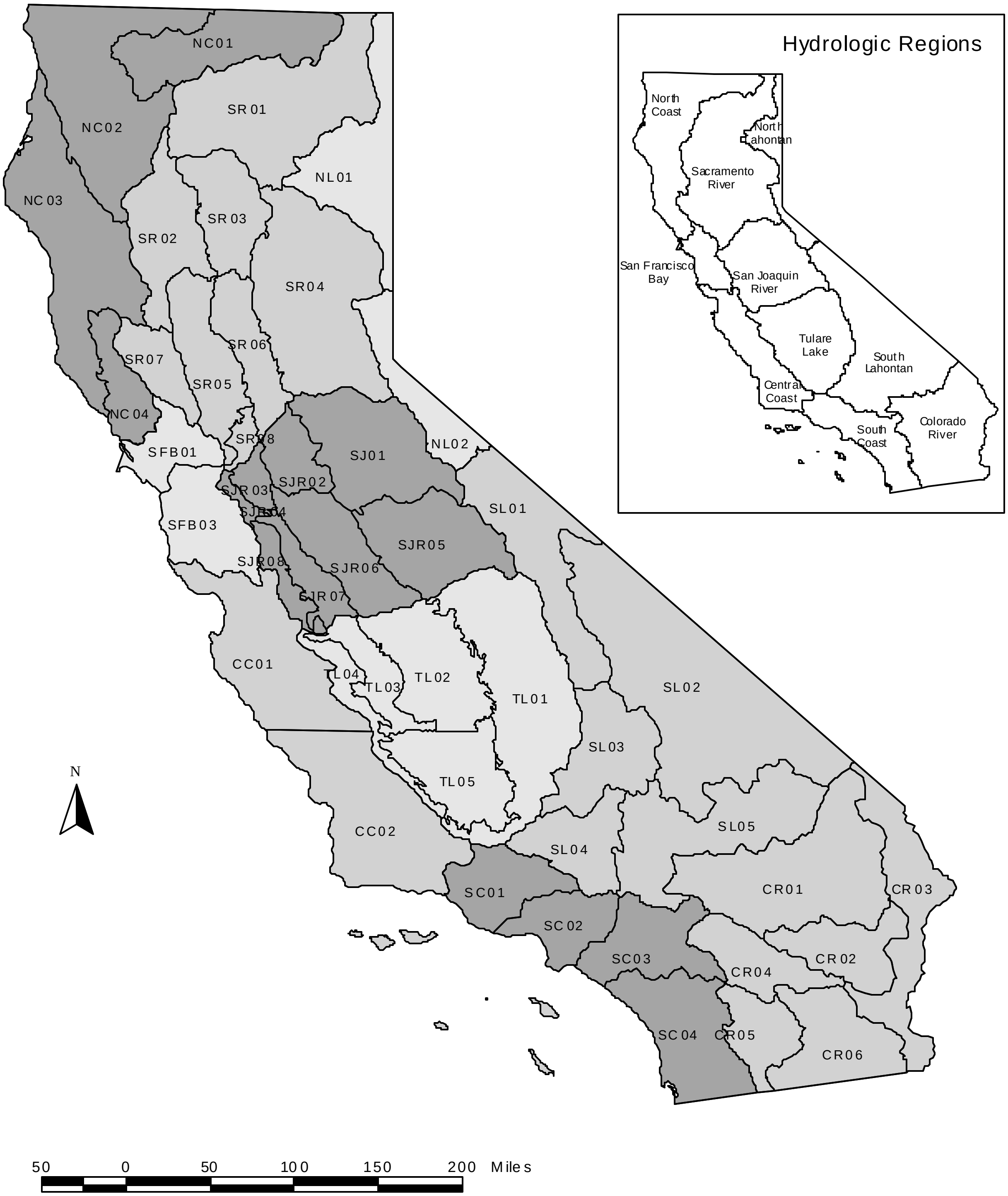
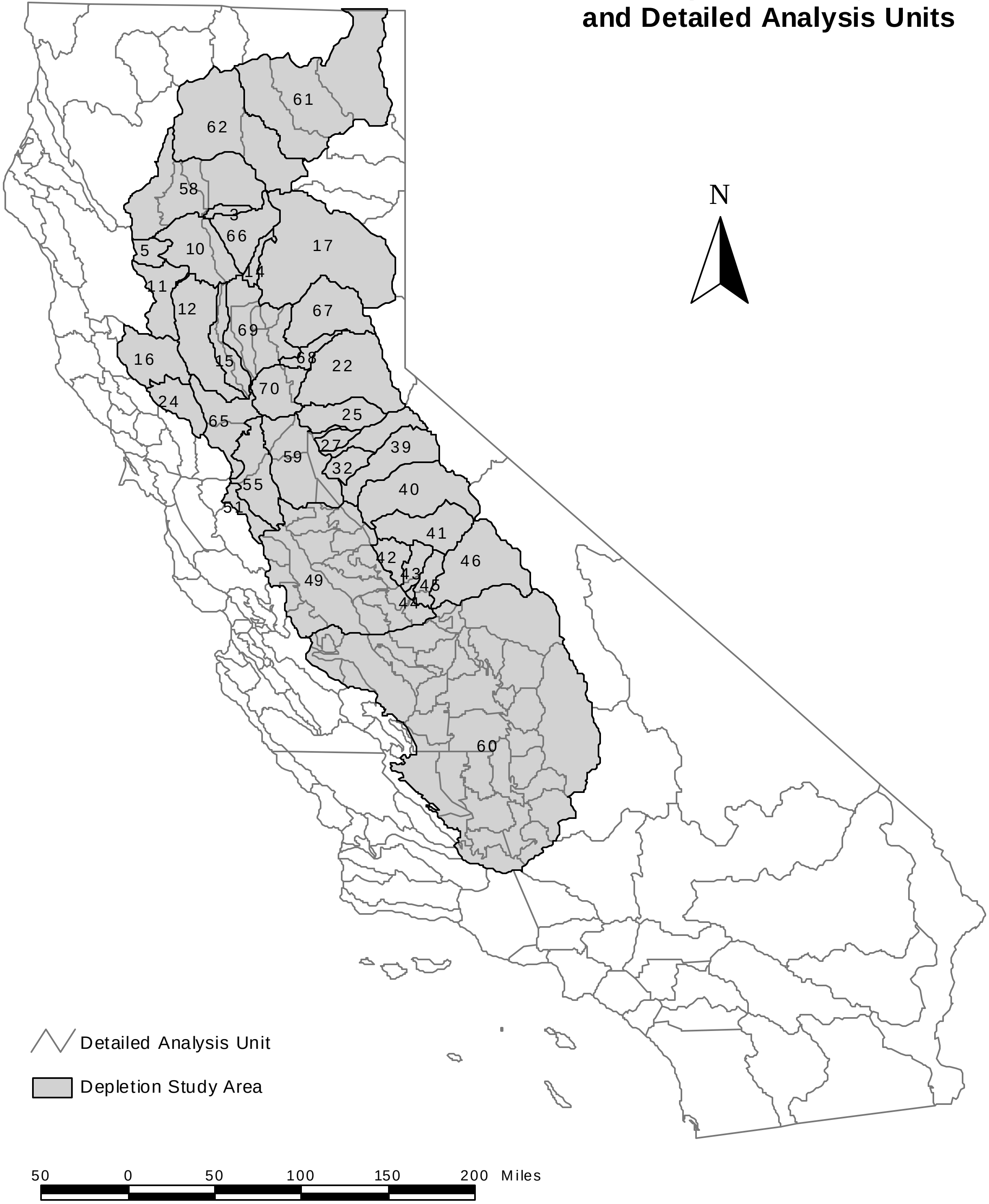


Figure I-4
Depletion Study Areas and Detailed Analysis Units



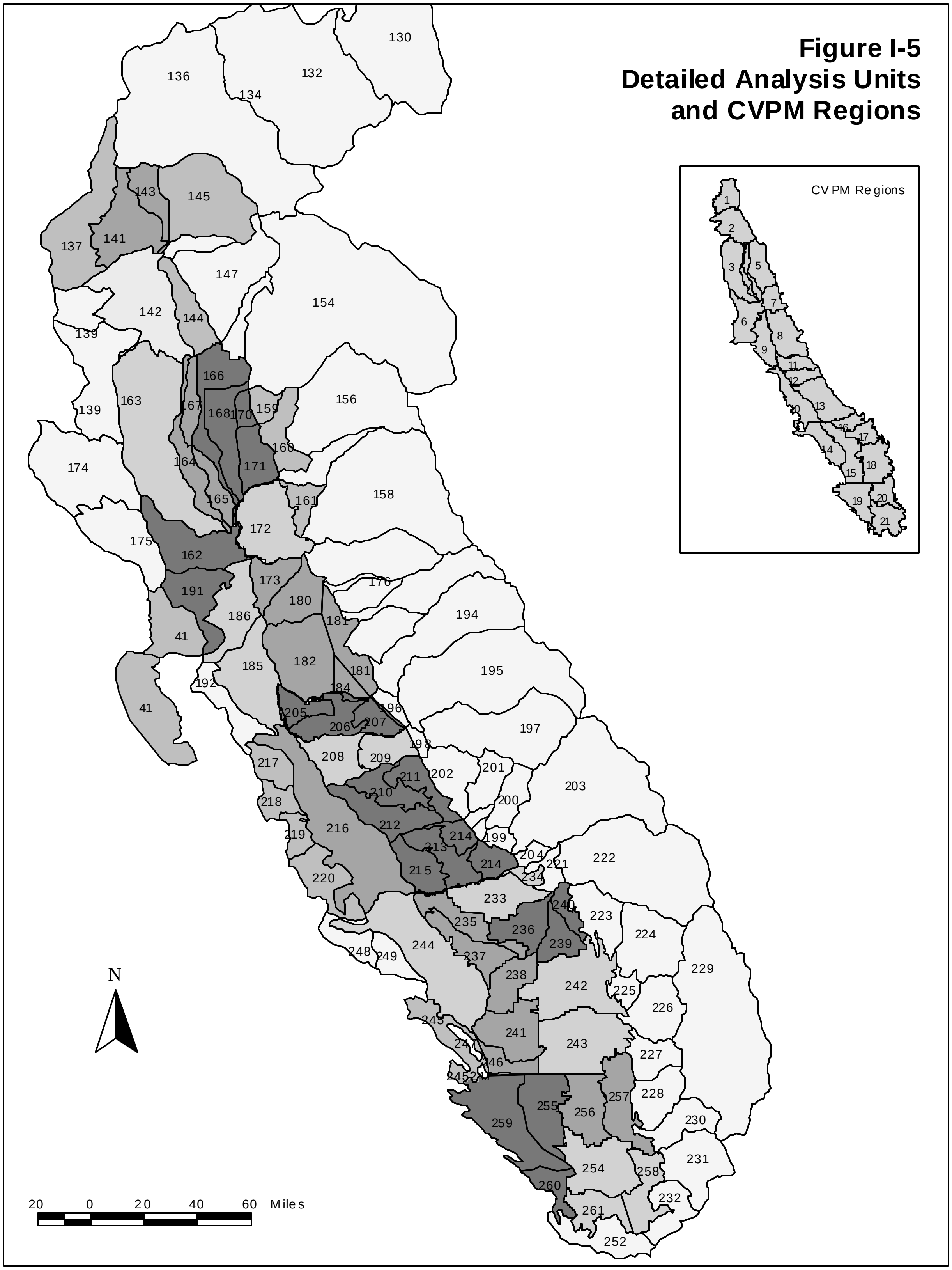


Figure I-5
Detailed Analysis Units and CVPM Regions

DEPLETION ANALYSIS

The depletion analysis is a hydrologic accounting method used by DWR to develop input for the Department's reservoir operation model DWRSIM. The depletion analysis has been used to obtain many of the rim flows to the Central Valley. However, shortcomings in the depletion analysis methodology preclude its use for estimating local water supplies within the Valley floor. The following sections give an overview of this methodology.

DWRSIM simulates the operation of the State Water Project (SWP) and the federal Central Valley Project (CVP). Model hydrologic inputs consist of a time series of monthly inflows and outflows for the October 1921-September 1994 period. The development of these inputs is a three-step process:

- Estimation of historic and projected agricultural and urban water demand using the consumptive use model;
- Use of the depletion analysis to estimate the effects of changes in land development on historic flows; and
- Calculation of inputs (IN's and YD's) to DWRSIM using the COMP model to aggregate the results of the two previous steps.

These steps are described briefly in the three sections below. The interested reader is referred to the very detailed description by Water Resources Management Inc. (1991) and DWR (1995).

Consumptive Use Model

The Consumptive Use (CU) Model, developed by DWR in association with WRMI, is used to calculate monthly agricultural and urban water demands. It is described in greater detail in Appendix K. Agricultural demand is calculated using a root-zone soil moisture budget. Urban demand is calculated as the sum of a landscape (outdoor) component and a domestic (indoor) water component. The landscape component is calculated using a soil moisture budget in a similar fashion to agricultural demand. The domestic or indoor demand is the product of the 2020 projected population and per capita urban consumption. Four summary tables from the CU Model are subsequently used in the depletion analysis. These are:

- Historic depletion of irrigated and urban areas (column #46);
- Historic replaced native vegetation consumptive use (column #47);
- Projected consumptive use (column #48); and
- Projected replaced native vegetation consumptive use (column #49).

The numbers refer to column headings in the text output files. Their precise meanings are explained in the following sections. Depletion refers to any process by which the water supply (either precipitation, surface water or groundwater) is reduced and not available for reuse. This occurs through open water and bare soil evaporation, plant transpiration, and return flows to a salt sink. Depletion can be sub-divided into soil-plant evapotranspiration and other depletions termed non-recoverable losses. Evapotranspiration is calculated using the CU model. Non-recoverable losses are harder to quantify. Agriculture and urban landscape non-recoverable losses are assumed to be 15% of ETAW in the foothills and 10% of ETAW in the Valley floor.

Column #46 includes non-recoverable losses. Non-recoverable losses are not included in column #48. DWR assumes 100% return flow from domestic or indoor urban use. It is therefore not considered in the depletion analysis.

Historic depletion of irrigated and urban areas (column #46)

This column is the sum of consumptive use of precipitation, the consumptive use of applied water for agriculture and urban use, and non-recoverable losses. The sum of these components represents the volume by which the water resource (precipitation, surface water and groundwater) are reduced or depleted by the historic development. The consumptive use of precipitation by a particular crop is the volume of monthly precipitation that contributes either directly to evapotranspiration or to an increase in soil moisture. It is that part that does not runoff or percolate below the root zone. For urban areas, consumptive use of precipitation is limited to areas categorized as either 'vacant lots' or 'lawns, shrubs and trees'. The volume of applied water consumptively used by agricultural and urban areas equals the evapotranspiration of agricultural crops and urban landscape.

Historic replaced native vegetation consumptive use (column #47)

This column represents the consumptive use of precipitation that would have occurred on the historic developed land under native conditions.

Projected consumptive use (column #48)

This column represents the consumptive use of both precipitation and applied water for the projected development.

Projected replaced native vegetation consumptive use (column #49)

This column represents the consumptive use of precipitation that would have occurred on the projected developed land under native conditions.

Depletion Analysis Model

The depletion analysis determines the effect of changes in land use, streamflow regulation and diversion on the historic flows in tributary streams to the Delta. The Sacramento and San Joaquin Valleys are divided into 37 depletion areas (DAs). Each DA corresponds to a drainage basin or service area for which the historic outflow is known or can be estimated from gage data. The projected outflow is calculated for each DA based on projected future operation of non-project reservoirs, projected land-use and projected diversions and return flows. The effect on streamflows of project reservoirs modeled explicitly in DWRSIM is removed. The process involves two steps as indicated in Figure I-6. Firstly, the effects of all development on historic streamflows is removed to obtain the unimpaired streamflow or flow that would have occurred under native conditions. The unimpaired historic outflow is calculated as:

- The historic outflow,
- Plus increase in flow from upstream depletion areas,
- Plus historic depletion of precipitation and applied water by the agricultural and urban sectors (column # 46 from CU model),
- Less historic replaced native vegetation consumptive use (column # 47 from CU model),

- Plus historic exports,
- Less historic imports,
- Plus changes due to historic flow regulation by local reservoirs.

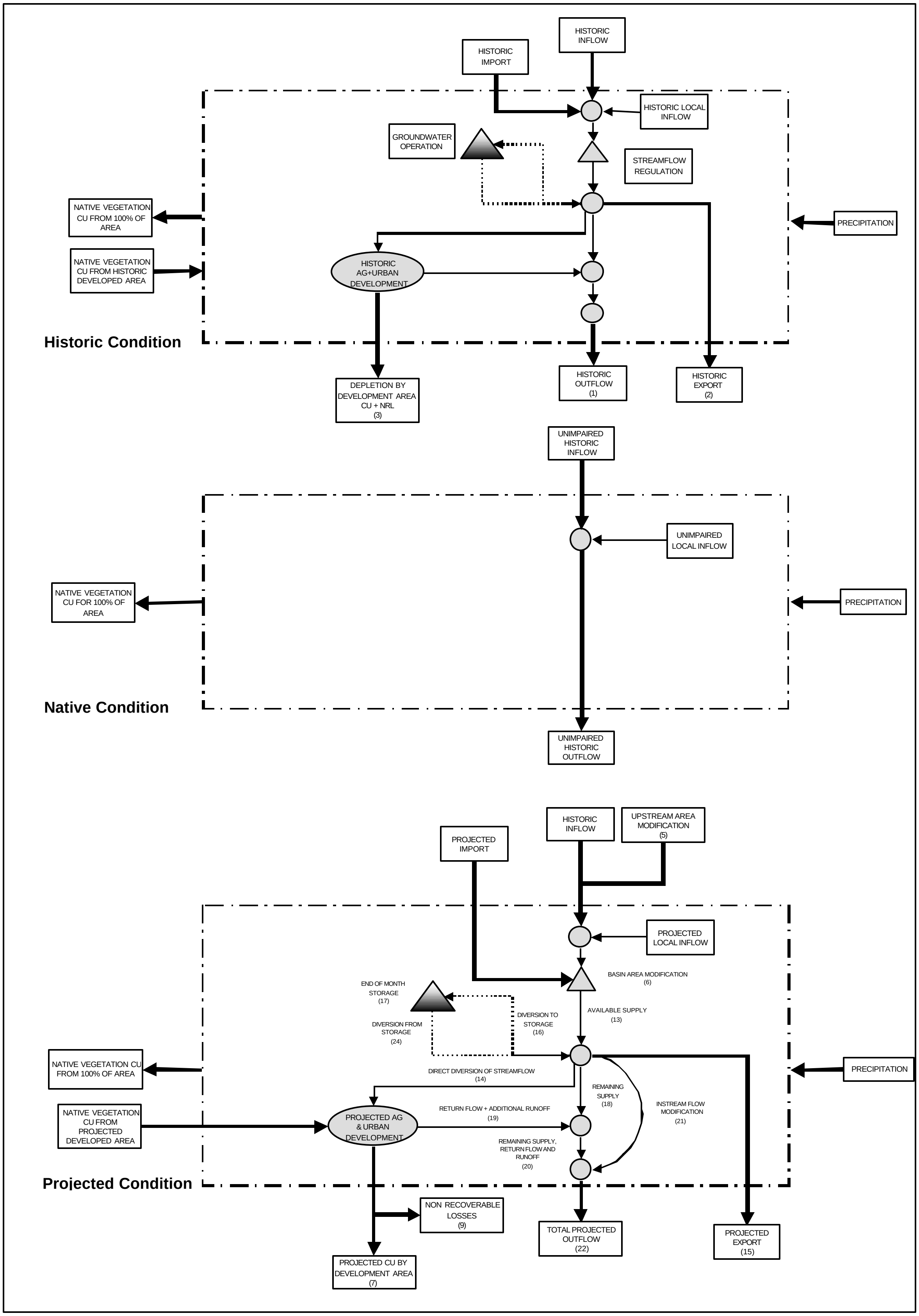
The second step is the calculation of projected outflows. This is:

- The unimpaired historic outflow (calculated from the above),
- Less projected decrease in flow from upstream depletion area,
- Less projected consumptive use (column #48 from CU model),
- Plus projected replaced native vegetation consumptive use (column # 49 from CU model),
- Less projected exports,
- Plus projected imports,
- Plus changes due to projected flow regulation in local reservoirs.

The depletion analysis output files or tables consist of 25 fields or columns of data.

(1) Historic outflow
(2) Historic export
(3) Historic depletion by developed areas
(4) Historic replaced native vegetation consumptive use (NVCU)
(5) Upstream area modification (changes between the historic and projected inflow from the upstream DAs)
(6) Basin area modification (differences between historic and projected imports and any changes in non-project reservoir operation)
(7) Projected consumptive use by developed areas
(8) Transport water
(9) Non-recoverable losses
(10) Projected CUAW
(11) Projected total water requirement
(12) Projected replaced NVCU
(13) Available supply
(14) Direct diversion of streamflow
(15) Projected export
(16) Diversion to storage
(17) End of month storage
(18) Remaining supply
(19) Return flow additional runoff
(20) Remaining supply, return flow and additional runoff
(21) Instreamflow modification
(22) Total projected outflow
(23) Total projected modification
(24) Diversion from storage
(25) Shortages

Figure I-6. Components of the Depletion Analysis



These different components are shown in Figure I-6. The projected consumptive use of applied water (column #10) is calculated as the difference between the projected consumptive use (column #48) and the replaced NVCU (column #49). Positive values represent months when consumtive use from the cultivated land exceeds the replaced native vegatation so that irrigation water must be diverted from the main streamflow. Negative values occur in months when the replaced native vegatation consumptively uses more precipitation and soil moisture than the cultivated land, and thus represent additional runoff.

The local water resource that contributes to the overall supply is the available supply (#13), less the basin area modification (#6), less the projected outflow (#24) from the upstream DAs, plus the additional runoff (negatives of #10).

In months when demand exceeds supply, project water is made available. Project water represents water available from state or federal reservoirs such as Lake Shasta. Project water is limited to contract amounts less deficiencies in dry years. For months when demand exceeds supply after the addition of project water, groundwater storage is introduced. Groundwater storage is set so that all the water requirements of the basin can be met. Withdrawals from storage occur in months when demand exceeds the available supply. Refill or recharge occurs when there is surplus water. The refill amounts are calculated according to an arbitrary algorithm that spreads the recharge over a six month period November to April.

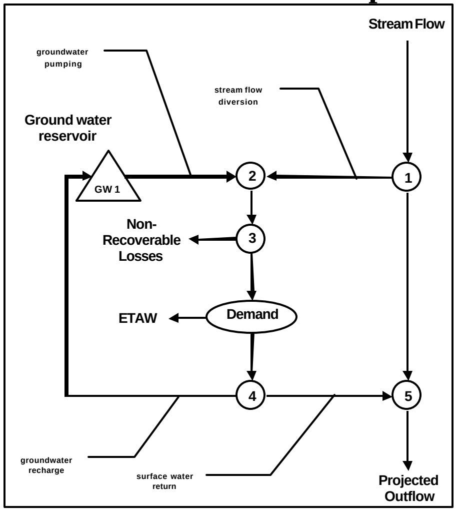
Limitations

The methodology of the depletion analysis was designed to determine the overall water supply availability at a time when the irrigated acreage in the Central Valley was increasing. It is not concerned with actual surface water diversions and groundwater pumping, but rather the effect of agriculture and urban development on the downstream availablity of surface water. The depletion analysis is unable to distinguish between historic agricultural demand that has been met by local surface water supplies and those met by groundwater pumping. Adjustments (i.e. DWRSIM accretions) to the historic flow record to account for historic agricultural water use are therefore a mixture of local surface water and net groundwater pumping. Diversions modeled by DWSIM within the Sacramento Valley represent the sum of net water consumptive use and surface water return flows. Assume that the consumptive use of irrigation water is ETAW. DWRSIM defines a basin efficiency, e, that is the ratio of ETAW to the prime diversion supply. The prime diversion supply is the sum of ETAW, non-recoverable losses and the surface return flow leaving the area. The basin efficiency factor is estimated from measured surface water diversions, measured return flows and estimated net groundwater extraction. This is illustrated in Figure I-7. DWRSIM does not represent flow paths between nodes GW1 to 2 and between nodes 4 to GW1. Instead the net effect of these two flow paths is added to flow path 1 to 2.

To isolate the separate components of surface water and groundwater, three additional pieces of information are required:

- historic groundwater pumping;
- irrigation ‘efficiencies’ – ratio of ETAW to AW at basin level; and
- ratio of returns to groundwater (via deep percolation) to returns to the surface water system via tailwater.

Figure I-7. Return Flows and the Depletion Analysis



As the depletion analysis does not consider the true effect of irrigation efficiency, it is not possible to accurately represent the conjunctive use of groundwater.

DWRSIM

Model Description

DWRSIM is the DWR's reservoir simulation model. The model is primarily used for planning and operations studies to assess the water available to the SWP under different operating scenarios. Hydrologic inputs for DWRSIM are prepared using the depletion analysis described in the preceding section. The consumptive use and depletion analysis data are converted into a time series of inflows (INs) and outflows (YDs) at the various control points of the model network. A series of different hydrologies have been developed for DWRSIM over the years. Hydrology based on Bulletin 160-98 2020 projected land use is referred to as "HYD-D-2020. For a given set of hydrologic inputs, DWRSIM regulates the water supply to meet all prescribed Delta standards, flood control requirements, minimum instreamflow requirements, and as far as possible project and non-project water requirements. For a given study, deficiencies may be applied to deliveries in dry years. DWRSIM does not model groundwater pumping dynamically. Historic levels of groundwater use are built into the INs.

Input data for CALVIN

Many of CALVIN's inflows to reservoirs in the Central Valley (excluding the Tulare Basin) have been taken directly from DWRSIM's input files. However, use and interpretation of INs and YDs are complicated by a series of factors:

- INs include some historic level of groundwater use;
- DA 10, DA 12 and DA 15 have been pre-operated so that INs (e.g. IN30 and IN61) include runoff from local runoff, gains and losses to groundwater, and return flows from urban and agricultural diversions;
- Canal imports and exports between depletion areas (with the exception of YD31) are built into the INs and YDs and are not modeled explicitly;

- The depletion analysis already builds in a certain level of deficiency in calculating the delivery requirement in dry years; and

- Ds meet only the net diversion requirement. Demand is offset against changes in land use that result in a reduced depletion compared with native vegetation. Urban development, in particular, offsets agricultural demand through increased runoff from impervious surfaces.

CVGSM

As described above, it is not possible to separate the surface water and groundwater components of local water supplies using the depletion analysis. Input for CALVIN for depletion areas within the Central Valley floor have, therefore, been taken from the Central Valley Ground-Surface Water Model (CVGSM) model results.

Model Description

CVGSM is a physically based hydrologic model of the Central Valley. The model is a particular application of the Integrated Groundwater Surface Water Model (IGSM), which has been developed over the last two decades. The surface hydrologic component includes a stream network to simulate streamflow, surface water diversions, return flows and streamflow accretions. The surface and groundwater components are linked via a root-zone soil moisture balance and flow through an unsaturated zone to the water table. The flow components of the root-zone model are evapotranspiration, infiltration and deep percolation. The model is described in greater detail in Appendix J.

The current version of CVGSM was developed as part of the CVPIA Programmatic Environmental Impact Statement (USBR 1997). This model simulates water operations for the 69-year period October 1921 to September 1990 using a monthly time step. Various policy scenarios were examined using the model as part of the CVPIA PEIS. Data used in CALVIN are based on the input and output from the “No-Action Alternative”.

Figure I-8 shows the stream network represented in CVGSM, superimposed on the finite element grid. The network consists of 38 streams and four internal drainage canals or bypasses. CVGSM does not include a reservoir simulation component. The stream network covers the floor of the Central Valley that lies downstream of the major surface water reservoirs. To analyze future water availability, CVGSM is coupled with reservoir simulation models. Rim flows are specified in CVGSM input files and are derived from:

- USGS gage data;
- DWR’s depletion analysis;
- Output from simulation models (DWRSIM, PROSIM and SANJASM).

Table I-5 (1 of 3). Summary of Depletion Analysis

DA	Projected Outflow	Local Reservoir	Basis for Reservoir Basin Modification	Projected Imports into DA	Projected Exports from DA	Land Use	Comment
3	Paynes Creek	None		None	None	Historic	
5	Thomes Creek & Elder Creek	None		None	None	Historic	
11	Stony Creek below Black Butte Reservoir	East Park Stony Gorge Black Butte	DWR 1982 Operation Study	None	None	2020	
14	Butte Creek & Little Chico Creek	Paradise	No adjustment	None	None	Historic	
16	Cache Creek above Blue Ridge Reservoir	Yes	Borcalli, Ensign & Buckley 1985 Operation Study	None	None	2020	
17	Feather River above Lake Oroville	Ten reservoirs	DWR & PG&E Operation Studies	Slate Creek from DA 67	Hendricks, Miocene, Wilenor, Miners Ranch, Palermo, Forbestown to DA 69	Historic	Outflow includes Palermo Canal, excludes Kelly Ridge PH
22	American River above Folsom	Twelve reservoirs	DWR 1984 HEC 3 model	South Canal from DA 70 Camino Conduit from DA 25 Echo Lake Conduit from Lake Tahoe basin	Lake Valley to DA 68 PCWA to DA 70	Historic?	Inflow to Folsom same as historic after 1980
24	Putah Creek below Lake Berryessa	Berryessa	USBR 1980 Operation Study	None	None	2020	12 taf/yr assumed local depletion
25	Cosumnes River at Michigan Bar	Jenkinson	USBR Report	El Dorado ID from DA 22 (Folsom Lake)	Camino Conduit to DA 22	?	
27	Sutter Creek & South Fork Dry Creek	Amador	No adjustment	None	None	Historic	

Table I-5 (2 of 3). Summary of Depletion Analysis

DA	Projected Outflow	Local Reservoir	Basis for Reservoir Basin Modification	Projected Imports into DA	Projected Exports from DA	Land Use	Comment
29	Mokelumne River below Pardee Reservoir	Pardee	EBMUD 1985 Operation Study	None	Mokelumne Aqueduct to EBMUD	?	Jackson Valley ID and EBMUD exports from Pardee Reservoir
		Camanche			Jackson Valley ID to DA 59		
		Three minor reservoirs			Amador Ditch to DA 27		
					Mokelumne Hill Ditch to DA 32		
32	Calaveras River below New Hogan Reservoir	Yes	Murray, Burns & Kienlen 1963 Operation Study	None	None	Historic?	Since 1971 projected outflow equal to historic
39	N. & S. Forks of Stanislaus River above New Melones Reservoir	Yes	USBR Operation Study	None	None		
40	Tuolomne River below New Don Pedro Reservoir	Yes	Bechtel Operation Study	None	Tuolomne Canal		
41	Merced River below Lake McClure	Yes	Tudor Operation Study	None	Big Creek Diversion		
42	Burns, Bear, Owens & Mariposa Creeks	None		None	None		
43	Chowchilla River below Eastman Lake	Yes	Reservoir de-operated	None	None		
44	Berenda Creek	None		None	None		
45	Fresno River below Hensley Lake	Yes	USACE Operation Study	None	None		

Table I-5 (3 of 3). Summary of Depletion Analysis

DA	Projected Outflow	Local Reservoir	Basis for Reservoir Basin Modification	Projected Imports into DA	Projected Exports from DA	Land Use	Comment
46	San Joaquin below Millerton Lake	Eight reservoirs	USBR Operation Study	None	Soquel Ditch to DA 45 Friant-Kern Canal to DA 60 Madera Canal to DA 49	?	
61	Pitt River at Fall River Mills	Ten reservoirs	No adjustment	None	Fall River to DA 61	2020	Groundwater pumping and recharge included in analysis
62	Sacramento River above Shasta Dam	Shasta Five minor reservoirs	Historic effect of Shasta removed	Pitt River Power House from DA 61		2020	
67	Yuba below Englebright plus Deer Creek & Dry Creek	Nine reservoirs	DWR 1989 HEC3 model	Tarr Ditch from DA 69	Slate Creek to DA 17 Browns Valley and China Ditch to DA 69 Drum, South Yuba, Cascade and D-S canals to DA 68	?	
68	Bear River below Camp Far West	Camp Far West Combie Rollins	DWR HEC3 model	Lake Valley Canal from DA 22 Drum, South Yuba, Cascade and D-S canals from DA 67	Boardman & Towle, Bear River, Combie Canals to DA 70 Tarr Ditch to DA 69	?	

Notes:
1 Only DAs upstream of CVPM regions are listed.
2 No depletion analysis is undertaken for DAs 67 and 68.
3 Column 3 indicates existence of local surface storage reservoirs within DA.
4 Column 4 indicates that the historic record has been adjusted to account for projected reservoir operation.
5 Column 5 gives the basis for projected reservoir operation.
6 Column 6 indicates the basis for land use. Historic indicates that no change in land use is projected.

A mistake in the input hydrology made absolute figures reported in the draft CVPIA PEIS incorrect.

> *'Subsequent to the completion of the surface water modeling conducted for the PEIS, Reclamation and the Service have discovered an inconsistency in the PROSIM input hydrology that may cause the model to over estimate the potential flexibility of CVP operations. As a result, current PROSIM simulations may under estimate the use of CVP shortage and conversely over estimate water deliveries in some critical dry years.' (USBR 1997)*

Input data and model runs were subsequently partially revised and released in the Fall of 1999 for the Final PEIS. However the revised data was not used in CALVIN.

CVGSM output includes a monthly water budget for each stream reach. Stream reaches are defined by stream junctions. The components of the stream budget for each reach are:

- ❑ Upstreamflow;
- ❑ Tributary flow;
- ❑ Direct runoff from rainfall;
- ❑ Agricultural and urban return flows;
- ❑ Gains and losses from and to groundwater;
- ❑ Surface water diversions; and
- ❑ Downstreamflow.

Direct runoff from rainfall in CVGSM is calculated using the Soil Conservation Service (now the National Resource Conservation Service) Curve Number method (SCS 1985). Associated with each grid element are land use, soil characteristics, precipitation gage and gage weighting factor. The stream-groundwater interaction is calculated based on the stream stage, groundwater table and the hydraulic conductivity of the stream bed.

Several small streams and drainage areas along the perimeter of the Valley are not directly represented by CVGSM. These drainage areas lie outside the finite element grid but downstream of the upstream depletion areas from which the rim flows are derived. The contribution of these small drainage areas is included in the model indirectly by specifying the area, stream node to which it drains, the precipitation, and soil type.

Input Data for CALVIN

Local water supplies for CALVIN consist of the sum of direct runoff from rainfall, tributary inflow for streams not represented explicitly in CALVIN's network, and net gains from groundwater. Input and output data for the No-Action Alternative CVGSM model run have been taken from the CVPIA PEIS CD-ROM disc 2. Stream nodes and stream geometry data are given in cvgsm\pass1\cnjstrm.dat. The rim flows are given in cvgsm\naa\cnjinfl.dat. Model output for the stream budget is given in cvgsm\naa\strm2a_y.nea. Tables I-6 and I-7 summarize the results from the streamflow budget, listing for each stream or stream reach the average annual flow for each component.

The CVGSM simulation period ends September 1990, compared to September 1993 for CALVIN. Annual precipitation data for the water years 1991, 1992 and 1993 were compared with the historic record (as given in DWR's depletion analysis). Representative years were selected for each of these three years and CALVIN input taken from CVGSM model results for those years. Table I-8 shows the selected years for each depletion area.

Table I-6. CVGSM Streamflow Budget, Sacramento Valley

Stream Reach (R)	Upstream (taf)	Tributary (taf)	Surface Water Return (taf)	Runoff (taf)	Ground water Gain (taf)	Bypass (taf)	Diversion (taf)	Downstream (taf)
Sacramento R32		6,632	9	118	-5		36	6,717
Cow R33		459	3	14	39			515
Sacramento R 34	7,232		5	37	15			7,290
Cottonwood R35		585	3	63	2			653
Battle R36		348			15			363
Sacramento R 37	8,305		5	53	9		112	8,260
Payne R38		52			4			56
Sacramento R 39	8,315		3	92	39		304	8,145
Antelope R40		203	2	13	8			226
Sacramento R 41	8,371		1	2	-4			8,371
Elder R42		62	0	22	17			102
Mill R43		214	0	1	1			216
Sacramento R44	8,689		4	16	2			8,710
Thomes R45		207	1	21	-28			201
Sacramento R 46	8,911		2	11	3			8,928
Deer R47		380	3	6	2			391
Sacramento R 48	9,318		22	82	-14		778	8,630
Stony R49		386	12	78	-68		99	308
Big Chico R50		101	14	27	-4			138
Sacramento R 51	9,076			0	-26		206	8,844
Butte Creek R52		284	178	240	-20			683
Sacramento R 53	8,844		19	14	-53	1654		7,170
Glenn Colusa R54		783	116	183	2		776	308
Colusa Drain R55			85	82	26			194
Colusa Drain R56	501		119	136	10	158	82	527
Sacramento R 57	7,697		4	6	-23		722	6,963
Sutter Bypass R58	683		129	118	-5	-1654		2,578
Feather R59		3,980	60	129	37			4,205
Yuba R60		1,799	7	15	6		173	1,655
Feather R61	5,860		22	44	15			5,941
Bear R62		331	44	55	-6		107	317
Feather R63	6,258		3	5	2			6,268
Feather R64	8,846		22	17	-10		1,001	7,873
Sacramento R65	4,836		244	164	-106	1698		13,439
American R66		2,462	116	75	-52		279	2,324
Sacramento R67	5,763		64	133	-17	72	293	15,578
Cache R68		454	56	77	-174	-1927	127	2,213
Putah R69		294	29	45	-13		150	204
Yolo & Cache Slough R70	2,417		47	120	-14			2,570
Sacramento R71	8,148		15	50			966	17,246
Delta R72	2,332		2	32				22,367
Total Sacramento River HR		**20,016**	**14,70**	**2,396**	**-391**	**0**	**6,210**	

Table I-7. CVGSM Streamflow Budget, San Joaquin Valley and Tulare Basin

Stream Reach (R)	Upstream (taf)	Tributary (taf)	Surface Water Return (taf)	Runoff (taf)	Ground water Gain (taf)	Bypass (taf)	Diver-sion (taf)	Down-stream (taf)
San Joaquin River R31	5,038		4	44				5,086
Mokelumne South R30	1,037		12	41	-9		86	994
Cosumnes River R29		332	97	162	-41		12	539
Dry Creek R28		78	32	68	-47			131
Mokelumne River R27		422	48	84	-187			367
San Joaquin River R26	3,954		18	72				4,044
Calaveras River R25		139	81	110	-98		64	169
San Joaquin River R24	3,555		160	252	20		202	3,785
Stanislaus River R23		1018	40	11	132		651	551
San Joaquin River R22	2,941		45	12	6			3,004
Tuolumne River R21		1451	80	37	193		935	826
San Joaquin River R20	1,977		120	51	-32			2,115
Orestimba Creek R19		11	24	2	42			79
San Joaquin River R18	1,875		49	22	-49			1,897
Merced River R17		892	55	54	-22		596	383
San Joaquin River R16	1,427		60	17	-13			1,492
Bear Creek R15		41	51	75	-16			151
San Joaquin River R14	1,283		20	5	-32			1,276
Deadman's Creek R13		41	52	35	-26			102
San Joaquin River R12	1,039		121	32	-11			1,181
Chowchilla River R11		65	53	26	-27		55	62
San Joaquin River R10	967		39	9	-39			976
Fresno River R9		82	86	70	-142		52	43
San Joaquin River R8	632		247	68	-22			925
San Joaquin River R7		281	244	118	-178		12	453
Total San Joaquin River HR		**4,853**	**1,837**	**1,480**	**-598**		**2,665**	
Tule River R6		114	202	256	-105		44	1,131
Kaweah River R5		426	29	123	-20	200	358	
Fresno Slough R4			175	49	-20	0	25	178
Kings River R3	585		67	94	-5		33	708
Kings River R2		1,712	224	142	-244	0	1248	585
Total Kings	585	1,712	291	236	-250	0	1281	1,293
Kern River R1		687	160	95	-205	384	353	
Total Tulare Lake HR		**4,651**	**1,146**	**996**	**-850**	**584**	**3,342**	
TOTAL		**27,809**	**4,162**	**4,636**	**-1,589**	**584**	**10,936**	

Limitations

Direct runoff from precipitation is influenced by groundcover and land use. Stream-groundwater interaction is a function of stream stage and depth to the water table. It is assumed that CALVIN's prescribed reservoir releases will not differ enough from those assumed for CVGSM to significantly affect stream gains and losses. Similarly, it is assumed that differences in CALVIN's implied land use will not significantly change the volume and timing of direct runoff.

Table I-8. Representative Water Years for 1991-1993

Depletion Area	10/1990-09/1991	10/1991-09/1992	10/1992-09/1993
DA 58	WY 1939	WY 1937	WY 1974
DA 10	WY 1934	WY 1936	WY 1986
DA 12	WY 1989	WY 1951	WY 1958
DA 15	WY 1989	WY 1936	WY 1958
DA 69	WY 1968	WY 1975	WY 1942
DA 65	WY 1959	WY 1988	WY 1967
DA 70	WY 1930	WY 1945	WY 1976
DA 59	WY 1968	WY 1985	WY 1978
DA 55	WY 1959	WY 1928	WY 1982
DA 49	WY 1948	WY 1967	WY 1965
DA 60	WY 1948	WY 1967	WY 1965

Direct runoff is calculated using empirical formula. Resulting streamflow accretions do not match other models (e.g. SANJASM). In the CVPIA PEIS, only differences in streamflow accretions calculated by CVGSM for different policy alternatives are subsequently used in the surface water models. It is to be expected that CVGSM runoff estimates are order of magnitude.

The major parameter affecting direct runoff is the Curve Number (CN). For CVGSM, CN is estimated from soil characteristics established by the SCS during county soil surveys. Stream gains and losses are influenced by streambed hydraulic conductivity. For CVGSM, these were initially assumed to be 1-3 feet/day for perennial streams and 3-10 feet/day for ephemeral streams. All parameter values were subsequently adjusted during model calibration. The model was calibrated to groundwater levels at selected wells for the 1970-1980 period and to outflow from DSAs developed by DWR for the 1921-1980 period. The results of the calibration show that for the Sacramento Valley, peak historic flows are significantly greater for DA 15 and often greater for DA 58, 10 and 59. For the San Joaquin Valley, DA 49 has significantly lower peak historic flows compared to simulated values. Differences in streamflow for a groundwater model are relatively unimportant compared to differences in groundwater levels. However, these differences are important for CALVIN and indicative of the reliability of the data being used. Sensitivity analysis reveals that inflow to the Delta is most affected by estimates of potential crop evapotranspiration and precipitation (JMM 1990). No sensitivity for CN is reported. Table I-9 below shows the relative importance of the different streamflow components.

Table I-9. Streamflow Budget: Average Annual Flow 1921-1980 (taf) CVGSM Model Calibration

Upstreamflow and tributary	Direct runoff from rainfall	Agricultural and urban returns	Gain from groundwater	Surface water diversions
27,564	2,342	1,249	930	7,550

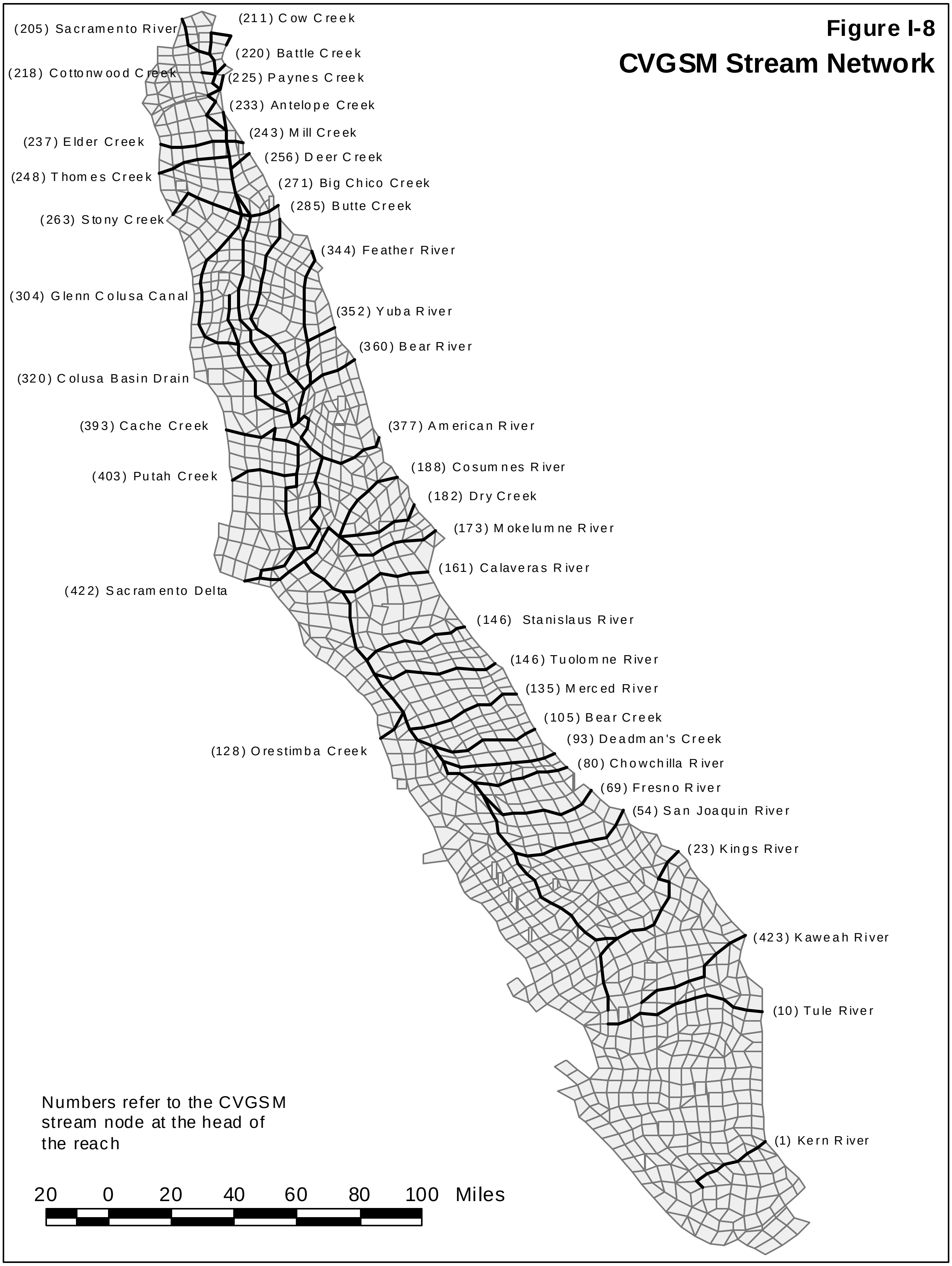


Figure I-8

CVGSM Stream Network

Numbers refer to the CVGSM stream node at the head of the reach

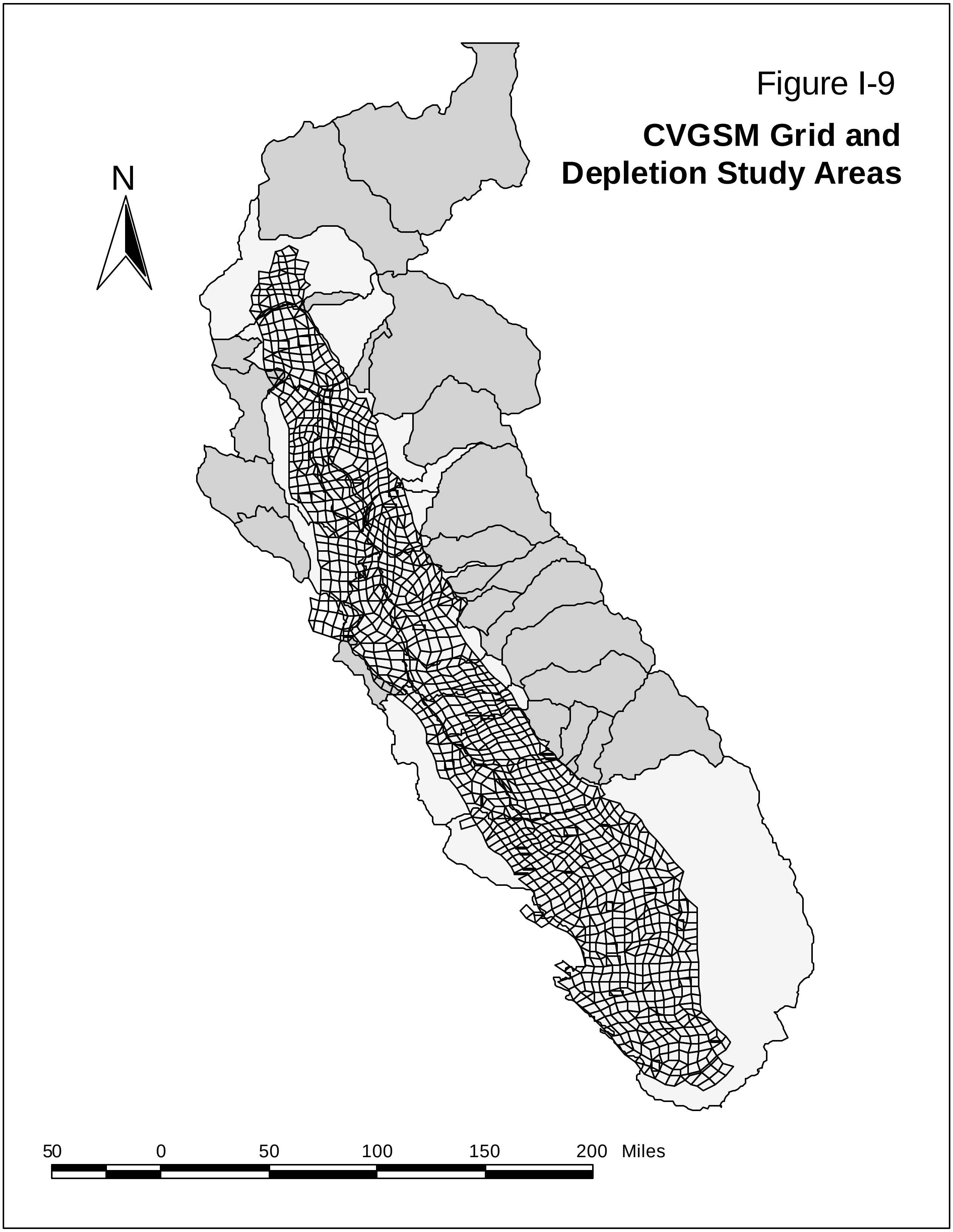


Figure I-9

CVGSM Grid and Depletion Study Areas

Other Sources of Data

CDEC

The California Data Exchange Center (CDEC) operates an extensive network of hydrometric measuring devices that include precipitation gages and river stage recorders. CDEC also exchanges hydrometric data with state, federal and other public agencies. These agencies include :

- National Weather Service (NWS): weather forecasts, river bulletins, full weather data;
- U.S. Bureau of Reclamation (USBR): reservoir operations, reservoir summary reports;
- U.S. Army Corps of Engineers (COE): precipitation, snow water content, reservoir operations, reservoir summary reports;
- Pacific Gas & Electric (PG&E): precipitation, snow water content;
- Sacramento Municipal Utility District (SMUD): precipitation, reservoir operations; and
- U.S. Geological Survey (USGS): river gage data, river flow rating tables and shifts

Data collected and stored by CDEC is disseminated through the web (http://cdec.water.ca.gov). Both historic and 'full natural flow' data are available. Flow data retrieved from CDEC have been used for estimating streamflows in the Tulare Basin.

SACRAMENTO RIVER HYDROLOGIC REGION

Introduction

The Sacramento River Hydrologic Region covers the entire watershed of the Sacramento River. It extends nearly 300 miles from the Oregon border to the Sacramento-San Joaquin Delta, an area of 26,960 square miles. At the head of the Sacramento Valley, inflow from the Sacramento, McCloud and Pit Rivers is impounded behind Shasta Dam. Downstream, the Sacramento River flows several hundred miles before entering the Delta near Hood. The major tributaries to the Sacramento River are the Feather and the American, which originate within the Sierra Nevada range. The Yuba River is the main tributary of the Feather River.

The Sacramento River Index is used as a measure of Northern California's water supply. It is based on Water Right Decision 1485 and is the sum of the unimpaired runoff of the Sacramento above Bend Bridge (near Red Bluff), the Feather River inflow to Lake Oroville, the Yuba river at Smartville, and the American River inflow to Folsom. The 1906-1993 average is 17.8 maf (DWR 1993) compared with a basin average of 22.4 maf.

Climate

The climate varies considerably within the region. The Sacramento Valley has mild winters and hot dry summers with no significant precipitation from June to September. Average annual precipitation is approximately 18 inches. Between October and May, streams are supplied predominantly from direct runoff. From April through July, flows in the Sierra Nevada and Cascade streams are largely driven by snowmelt.

Land Use

Land use affects the volume and timing of local runoff. The 21 agriculture regions modeled in CALVIN are all located within the floor of the Central Valley. CVPM Regions 1-7 are found entirely within the Sacramento River Hydrologic Region. CVPM Regions 8 and 9 span the Sacramento and San Joaquin Hydrologic Regions. Table I-10 gives a breakdown of projected 2020 land use by CVPM region. Outside the Valley floor, agriculture is relatively sparse. Table I-11 lists the agricultural areas in the Sacramento Hydrologic Region, which are not explicitly represented by CALVIN.

Table I-10. Sacramento River Hydrologic Region, Projected 2020 Land Use (acres)

Region	Undeveloped	Developed	Agriculture	Urban	Total
CVPM 1	1,459,300	143,700	33,700	110,000	1,603,000
CVPM 2	522,100	232,900	199,600	33,300	755,000
CVPM 3	515,500	398,800	386000	12,800	914,300
CVPM 4	66,600	284,600	279,800	4,800	351,200
CVPM 5	444,140	465,800	384,800	81,000	909,940
CVPM 6	275,500	316,700	255,600	61,100	592,200
CVPM 7	99,300	392,700	108,100	284,600	492,000
CVPM 8	597,500	378,500	281400	97,100	976,000
CVPM 9 uplands	52,000	164,100	128,400	35,700	216,100
CVPM 9 lowlands	142,000	320,100	2,91,300	28,800	462,100
Note: Ag and Urban areas taken from CU model, undeveloped area from CVGSM.					

Table I-11. Agricultural Areas not included in CALVIN

Region not included in CALVIN	2020 Cropped Acreage
Shasta Lake-Pit River (PSA 01) all DAUs	139,400
Northwest Valley (PSA 02), DAU 137 and 139	2,500
Northeast Valley (PSA 03), DAU 147	1,200
Southeast (PSA 04), DAU 154, 156, 158	74,600
Southwest (PSA 07), all DAUs	23,800

The major urban area within the region is the Greater Sacramento metropolitan area. Other important communities include Vacaville, Dixon, Chico, and Redding.

Water Supplies

Table I-12 below lists the external flows in the Sacramento Valley and the Trinity River system that are represented in CALVIN. The average annual inflow is approximately 24 maf of which 0.9 maf is imported from the Trinity River.

Rim Flows

CALVIN represents nine depletion areas within the Sacramento Valley. These depletion areas receive rim flows from 11 upstream areas:

- DA 62, Sacramento River above Shasta Dam

- DA 3, Paynes and Seven Mile Creeks
- DA 66, Sacramento Valley, Northeast Streams
- DA 5, Thomes and Elder Creeks
- DA 11, Stony Creek above Black Butte Dam
- DA 16, Cache Creek above Rumsey
- DA 24, Putah Creek above Winters
- DA 14, Butte Creek and Little Chico Creek
- DA 17, Feather River above Oroville Dam
- DA 67, Yuba River above Dry Creek
- DA 68, Bear River above Wheatland
- DA 22, American River above Folsom Dam

As part of the CVP, water is imported from the Trinity River System (see later section). CALVIN therefore represents additional rim flows for:

- Trinity River inflow to Clair Engle Lake
- Local inflow to Lewiston Lake

Table I-13 compares rim flows between those obtained from the depletion analysis or DWRSIM and those used for CVGSM. As expected they closely match as the depletion analysis was used to develop CVGSM flows. However CVGSM flows were based on Bulletin 160-93 projected 2020 land use.

(a) Trinity River System

The Trinity River system is represented in CALVIN by two nodes representing Clair Engle Lake and Lewiston Lake downstream. Lewiston Lake is relatively small and is used to re-regulate releases from Clair Engle Lake. It is not modeled as a storage reservoir. Water released from Clair Engle Lake is either exported to Whiskeytown Lake via the Clear Creek Tunnel or is released from Lewiston into the Trinity River to meet minimum instreamflow requirements. The Trinity River inflow to Clair Engle Lake and local inflow to Lewiston Lake are taken directly from DWRSIM input files (IN1 and IN94).

(b) DA 62, Sacramento River above Shasta Dam

DA 62 and DA 61, which lies upstream, cover the Sacramento watershed upstream of Shasta and include the Sacramento, McCloud and Pit Rivers. The projected outflow from DA 62 is equal to the projected inflow to Lake Shasta. This is calculated as the historic flow modified to remove the effects of Lake Shasta and to account for changes in upstream land use. Lake Shasta marks the northern extent of CALVIN's network. Inflow to the lake is taken directly from DWRSIM (IN4).

Table I-12. Sacramento River HR, CALVIN External Flows (taf)

DA	Description	Source	Inflow 10/21-09/90	Inflow 10/21-09/93
(a) Rim Flows				
-	Trinity River inflow to Clair Engle Lake	DWRSIM (IN1)	1,225	1,217
-	Local inflow to Lewiston Lake	DWRSIM (IN94)	47	46
	(Export to Sacramento HR)		*(904)*	*(884)*
	Clear Creek inflow to Whiskeytown Lake		264	263
DA 62	Inflow to Shasta Lake	DWRSIM (IN4)	5,571	5,525
DA 3	Inflow from Paynes and Seven Mile Creeks to DA 10	Depletion Analysis	52	51
DA 66	Inflow from North-East Streams (Antelope, Mill, Dry, Deer & Big Chico Creeks) to DA 10	Depletion Analysis	903	902
DA 5	Elder Creek inflow to DA 10	USGS gage data	205	204
DA 5	Thomes Creek inflow to DA 10	DWRSIM (IN75)	66	66
DA 11	Inflow to Black Butte Reservoir	Depletion Analysis	399	396
DA 17	Inflow to Lake Oroville plus u/s diversions to DA 69	DWRSIM (IN6)	3,944	3,900
DA 17	Inflow from Kelly Ridge to Feather River	DWRSIM (IN7)	125	126
DA 14	Inflow from Butte and Little Chico Creeks to DA 69	Depletion Analysis	358	354
DA 67	North Fork Yuba River inflow to New Bullards Bar	HEC 3 (DWR)	1,226	1,213
DA 67	Middle and South Forks Yuba River inflow to Englebright Lake	HEC 3 (DWR)	431	424
DA 67	Deer Creek inflow to Yuba River	HEC 3 (DWR)	69	68
DA 67	French Dry Creek inflow to Yuba River	HEC 3 (DWR)	133	133
DA 68	Bear River inflow to Camp Far West plus u/s diversions to DA 69 and DA 70	HEC 3 (DWR)	720	712
DA 68	Accretion: Camp Far West to Wheatland gage	HEC 3 (DWR)	3	3
DA 16	Inflow to Clear Lake and Indian Valley Reservoir	Depletion Analysis	501	499
DA 24	Inflow to Lake Berryessa	Depletion Analysis	375	372
DA 22	North & Middle Forks American inflow to Folsom	DWRSIM (IN17)	1,395	1,374
DA 22	South Fork American inflow to Folsom Reservoir	DWRSIM (IN8)	1,324	1,311
(b) Local Water Supplies				
DA 58	Cottonwood Creek		558	554
DA 58	gains	CVGSM	1,301	1,301
DA 58	losses	CVGSM	0	0
DA 10	gains	CVGSM	225	231
DA 10	losses	CVGSM	-32	-32
DA 12	gains	CVGSM	449	454
DA 12	losses	CVGSM	-10	-9
DA 15	gains	CVGSM	28	29
DA 15	losses	CVGSM	-93	-93
DA 69	gains	CVGSM	654	661
DA 69	losses	CVGSM	-13	-13
DA 65	gains	CVGSM	129	130
DA 65	losses	CVGSM	-88	-89
DA 70	gains	CVGSM	104	105
DA 70	losses	CVGSM	-46	-46
DA 70	American River accretions Folsom to Fair Oaks	DWRSIM IN9-YD85	-33	-33
Total External Flows to Sacramento River HR exc. Trinity River			21,197	21,047
Total External Flows to Sacramento River HR inc. Trinity River			22,101	21,931

Notes: Although Clear Creek is completely contained within DA 58, Clear Creek inflow to Whiskeytown is treated as a rim flow

Gains and losses are months when the net effect on the water supply is positive or negative rather than representing different components of flow within a month

Table I-13. Sacramento Valley, Comparison of Average Annual Rim Flows (taf)

DA	Description	Source[4]	CVGSM 10/21-09/90	Depletion Analysis/ HEC3/DWRSIM[7] 10/21-09/90
DA 58	Sacramento River below Keswick Dam	PROSIM	6,632	6,642[1]
DA 66	Antelope, Mill, Deer and Big Chico Creeks	Depletion	898	902
DA 3	Paynes and Seven Mile Creeks	Depletion	56	52
DA 5	Thomes Creek	Depletion	207	205
DA 5	Elder Creek	Depletion	62	66
DA 11	Stony Creek	Depletion	386	390[2]
DA 14	Butte and Chico Creeks	Depletion	284[9]	358
DA 17	Feather River below Oroville Dam	PROSIM	3,980	3,769[3]
DA 67	Yuba River below Englebright	Depletion	1,799	1,824[5]
DA 68	Bear River below Camp Far West Dam	Depletion	331[6]	335[6]
DA 16	Cache Creek above Rumsey	Depletion	454	501
DA 24	Putah Creek below Lake	Depletion	294	375
DA 22	American River below Folsom Reservoir	PROSIM	2,462[8]	2,498

Notes
1 Sum of Shasta dam release (5486), Spring Creek Tunnel diversion (1030) and Clear Creek inflows to Sacramento River (126)
2 DWRSIM IN76
3 Sum of Oroville release (3,874), plus Kelly Ridge inflow (125) less Palermo canal diversion (20)
4 PROSIM run NAA_G23, Depletion Model run 2020C9A
5 Includes PCWA diversions
6 Includes South Sutter WD diversion, does not include Camp Far West ID
7 DWRSIM run 514, Depletion Model run 2020D09A
8 Does not include diversions to PCWA from North Fork, Natomas and Folsom Pumps (149taf in NAA/PROSIM)
9 Does not include inflow from 63 sq. mile 'small watershed' that is outside model boundary

(c) DA 3, Paynes and Seven Mile Creeks

DA 3 is a small drainage area on the east bank of the Sacramento River. It contains Paynes and Seven Mile Creeks. These creeks flow into the Sacramento River between the Red Bluff Diversion Dam and Bend Bridge. The depletion analysis assumes that the projected outflow is the same as historic flow. In DWRSIM, the flow from DA 3 is included in IN77. The inflow for CALVIN is taken from the depletion analysis.

(d) DA 66, Sacramento Valley, Northeast Streams

DA 66 is the watershed for a series of creeks that flow into the Sacramento River from the north-east. They include Antelope Creek, Mill Creek, Dry Creek, Deer Creek and Big Chico Creek. As there is little development within DA 66, the depletion analysis assumes that the projected outflow is the same as the historic flow. In DWRSIM, the inflow from DA 66 is included in IN77. The inflow for CALVIN is taken directly from the depletion analysis. Data were available only up to September 1992. From an inspection of the Red Bluff precipitation gage, annual precipitation for the 1992/93 year is similar to 1937/38. The time series was extended by adding flows for these 12 months to the end of record.

(e) DA 5, Thomes and Elder Creeks

DA 5 is the drainage area for Thomes Creek and Elder Creek, which flow into DA 10 from the west. There are no major dams in the depletion area but there are small diversions for irrigation from both creeks. Elder Creek is the smaller of the two creeks. It rises in the Coastal range, draining an area of 142 square miles. It joins the Sacramento River 12 miles south of the city of Red Bluff at RM 230. Thomes Creek drains an area of 203 square miles on the west side of the Sacramento Valley. Runoff originates in the Coastal Range and enters the Sacramento River at RM 224, four miles north of the city of Corning. Below the USGS gage at Paskenta, the creek is usually dry during the summer months. In total, it contributes 2-3% of the Sacramento River flow.

As there is little development within the drainage area, the depletion analysis assumes that the projected outflow is the same as the historic flow. This is the combined flow of Elder Creek near Paskenta and the flow of the Thomes Creek at Paskenta. The CALVIN rim flow for Thomes Creek is taken from DWRSIM (IN75). The rim flow for Elder Creek is taken as the difference between IN75 and the projected outflow for DA 5 from the depletion analysis. As the depletion analysis is available only up to September 1992, the October 1992-September 1993 period has been obtained from USGS gage data (station #11379500, Elder Creek near Paskenta).

(f) DA 11, Stony Creek above Black Butte Dam

DA 11 is located on the west side of the Sacramento Valley and lies immediately upstream of DA 10. It consists of the Stony Creek watershed above Black Butte Reservoir. The creek drains an area of 738 square miles and joins the Sacramento River south of Hamilton City. Flows in Stony Creek are regulated by Black Butte Dam and East Park Dam and Stony Gorge Dam that lie upstream. These two upstream dams form part of the CVP Orlando Project that provides water for local irrigation. The Orlando Project is not modeled in CALVIN. Black Butte Dam, owned and operated by USACE, provides both flood control and irrigation supply. The north and south main canals take off immediately below the dam, providing irrigation water for agriculture in DA 10. The Glenn Colusa Canal crosses Stony Creek downstream of Black Butte Dam. A seasonal gravel dam is used to divert all remaining flow into the canal.

The projected outflow from DA 11 corresponds to inflow IN76 in DWRSIM and is equivalent to the projected outflow from Black Butte Dam. Black Butte Reservoir is modeled explicitly in CALVIN. Projected inflow to the reservoir has been calculated using input data for the depletion analysis. Before October 1980, the projected inflow is based on a 1982 DWR reservoir operation study. After this date, the inflow is calculated as the actual releases plus evaporation less changes due to storage regulation. Reservoir storage and evaporation were obtained from the USACE, Sacramento District.

(g) DA 16, Cache Creek above Rumsey

DA 16 is the drainage area for Cache Creek above Rumsey. The area includes Clear Lake on the main stem of Cache Creek, Indian Valley Reservoir on the North Fork of Cache Creek, and the Bear Creek/Mill Creek watershed. There are no upstream depletion areas. The projected outflow from the area is the projected inflow to the Blue Ridge Reservoir.

This part of the west Sacramento Valley is not modeled in DWRSIM. Outflow from the region is represented in DWRSIM as an inflow to the Delta at node CP55 from the Yolo Bypass. CALVIN represents Clear Creek and Indian Valley as a single aggregated reservoir with a single inflow. Local water use is not represented dynamically in the model.

DWR has estimated the unimpaired flow for Cache Creek at Rumsey for the 1921-1993 period. Data from the depletion analysis for DA 16 are only available up to September 1978. Comparing the average annual flow from these two data sets provides a measure of local projected water use within the DA. The average unimpaired flow is 468 taf/yr compared with a projected outflow from DA 16 of 408 taf/yr. From the depletion analysis, the consumptive use of applied water is 62 taf with an additional 6 taf from non-recoverable losses. The projected developed area results in an additional 10 taf runoff compared with native vegetation. This explains 59 taf of the 60 taf difference. The unimpaired flow is used for flow into CALVIN's aggregate reservoir. Local depletion is extracted downstream. After 1978, the local depletion is taken as the monthly average for the 1921-1978 period. This approach assumes that all demand occurs at or downstream of Clear Lake/Indian Valley and that all the unimpaired flow at Rumsey is available as inflow to the modeled storage.

(h) DA 24, Putah Creek above Winters

DA 24 is the Putah Creek watershed above Winters. It includes Lake Berryessa and the surrounding catchment. There are no upstream depletion areas. The outflow is the flow at Putah Creek 1.3 miles downstream of Monticello Dam at the Winters gage. CALVIN models the operation of Lake Berryessa explicitly so that the required rim flow is the projected 2020 reservoir inflow.

DWR has estimated the unimpaired flow for Putah Creek at Winters for the 1921-1993 period. Data from the depletion analysis for DA 24 are available up to September 1992. The projected upper basin depletion is 12 taf. Subtracting this from DWR's unimpaired flow estimate results in an average annual inflow of 352 taf. This compares with a projected outflow from the depletion analysis of 312 taf. It is assumed that the difference corresponds to evaporation losses from the lake.

(i) DA 14, Butte Creek and Little Chico Creek

DA 14 is a small drainage area to the northwest of the North Fork of the Feather River. Paradise Reservoir is the only reservoir within the depletion area. Butte Creek and Little Chico Creek at Chico are the outflows from the depletion area. The depletion analysis assumes that the projected outflow is the same as the historic flow. Results from the depletion analysis are available up to September 1992. The projected outflow has been extended to September 1993 using USGS daily streamflow data for Butte Creek near Chico (station #11390000). From correlation with the depletion analysis for the October 1930-September 1992 period, it was estimated that Butte Creek accounted for 70.5% of the flow. The average annual projected outflow from the watershed for the 1921/22-1992/93 period is 352 taf.

(j) DA 17, Feather River above Oroville Dam

The Feather River is the largest tributary to the Sacramento River. It covers a drainage area of 3,607 square miles with a median historical unimpaired runoff of 3.8 maf/yr with a range of 1.0 to 9.4 maf/yr (USBR 1997). Flows in the river are regulated by Oroville Dam, which was completed in 1967 as part of the SWP. Oroville is the lowest dam within the watershed sited just downstream of the confluence of the West Branch and the North, Middle and South Forks of the Feather River.

CALVIN models the operation of Oroville and the Lower Feather watershed below the dam. Rim flows to CALVIN consist of projected inflows to Lake Oroville and upstream canal exports that supply water to downstream areas. These include diversions to the Hendricks and Miocene-Wilenor Canals from the West Branch, and diversions to the Forbestown Ditch and Miners Ranch Canal from the South Fork of the Feather. A proportion of the Miners Ranch Canal returns to the Feather River immediately downstream of Lake Oroville after passing through the Kelly Ridge Powerhouse. All other canal water is exported to DA 69 (the lower Feather River watershed). Rather than model the operation of the Kelly Ridge Powerhouse explicitly in CALVIN, return flows from the powerhouse have been subtracted from upstreamflows in the Feather River. Exports to the Miners Ranch Canal are then considered to be exclusively for irrigation.

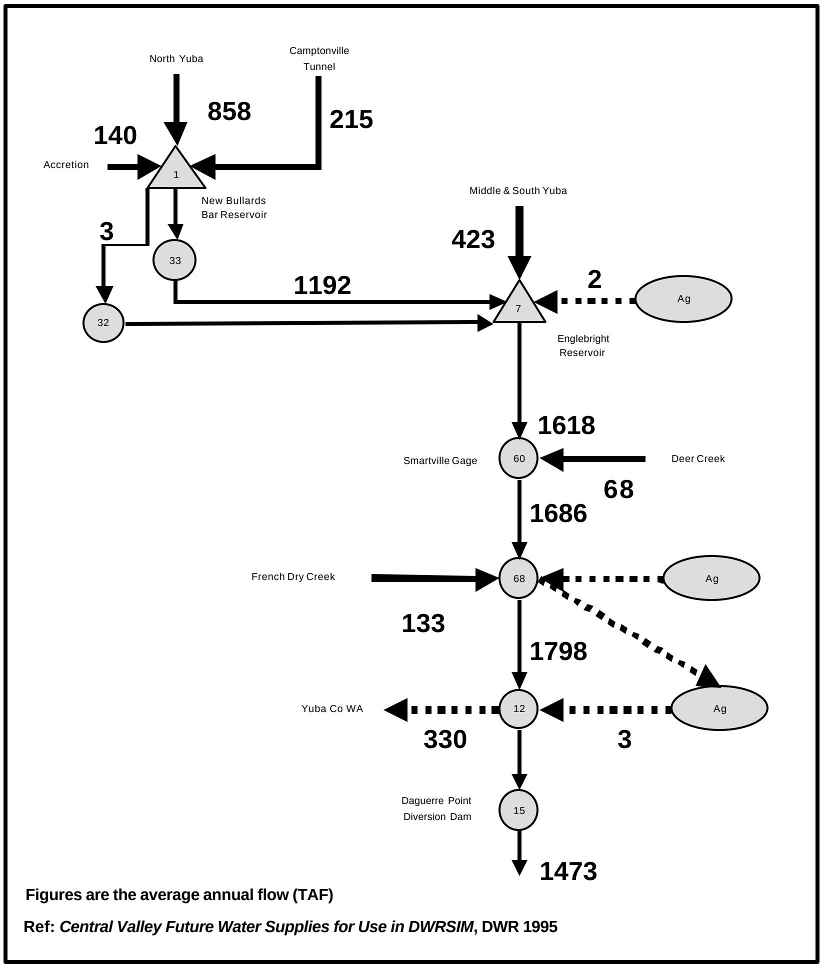
Inflow to Lake Oroville and the Kelly Ridge return flow are taken directly from DWRSIM, inflows IN6 and IN7, respectively. IN6 includes flow in the Palermo Canal that offtakes from Oroville Lake. IN6 is equal to the historic outflow modified for changes in imports and exports (Miners Ranch Canal, Forbestown Ditch, Hendricks & Wilenor, Slate Creek) and for storage development within the basin. No adjustment has been made for land use changes. The projected exports for the Miners Ranch Canal and Forbestown Ditch were obtained from DWR (file: hq698_96/feather). The average projected export (excluding Kelly Ridge) of these two canals is 36 taf/yr. The rim flow for CALVIN was calculated as the sum of IN6 and the projected exports less IN7 (the Kelly Ridge inflow).

(k) DA 67, Yuba River above Dry Creek

The Yuba River is the largest tributary to the Feather, contributing about 40% of the flow (USBR 1997). The river rises in the Sierra Nevada and drains an area of 1,339 square miles before joining the Feather River near Marysville and Yuba City. There are seven major reservoirs located in the Yuba River watershed. By far, the largest is New Bullards Bar on the North Fork, completed by Yuba County WA in 1969. Only two of these reservoirs are modeled explicitly in CALVIN: New Bullards Bar and Englebright Lake. The major diversion point for irrigation and water supply is at Daguerre Point Dam in the lower watershed, 12.5 miles below the Narrows Dam that impounds Englebright Lake. DA 67 represents the Yuba River watershed upstream of Englebright reservoir plus the watersheds of Deer Creek and Dry Creek that flow into the Yuba approximately one mile and ten miles downstream of the reservoir. To calculate outflow from the system, DWR uses a modified version of USACE's HEC3 model. Figure I-10 below summarizes the results of the model for the October 1921-September 1993 period. The average inflow to New Bullards Bar is 1,213 taf. Inflow to Englebright, in addition to releases from New Bullards Bar, total 426 taf. Inflows from Deer Creek and French Dry Creek average 68 taf and 133 taf, respectively.

Tributaries to the Feather River are not modeled explicitly in DWRSIM. Their effect is incorporated into IN32/37 that combines inflow from the Bear and Yuba Rivers with local water supplies for DA 69.

Figure I-10. Yuba River HEC-3 Model



Figures are the average annual flow (TAF)

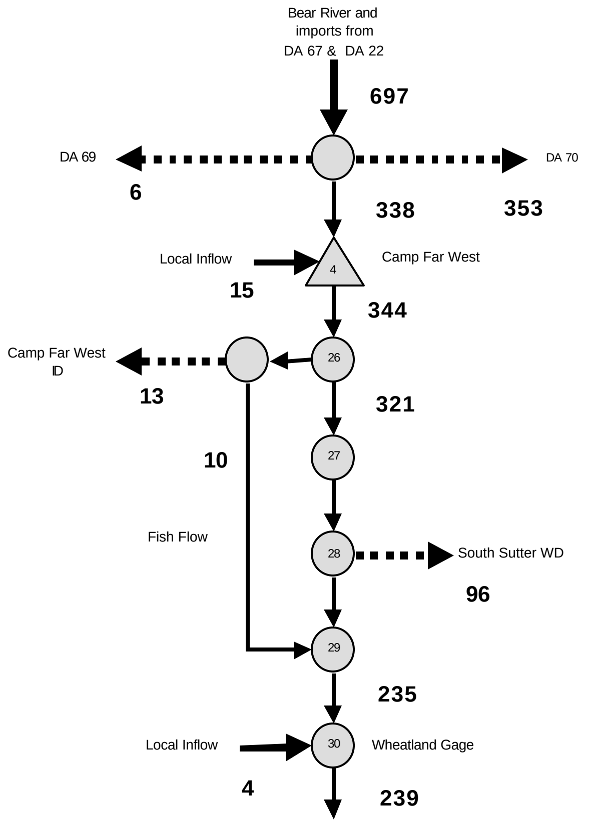
Ref: ***Central Valley Future Water Supplies for Use in DWRSIM*****, DWR 1995**

(l) DA 68, Bear River

The Bear River watershed lies between the Yuba and American rivers. The Bear River is a major tributary to the Feather River and flows into the river at East Nicolaus, approximately 13 miles south of Marysville. DA 68 covers the Bear River watershed upstream of the Wheatland gage. Flow in the Bear River is regulated by Camp Far West Reservoir, Rollins Reservoir, and Lake Combie on upstream tributaries. There are imports into the depletion area from DA 67 and DA 22 and exports to DA 69 (Tarr Ditch) and DA 70 (Boardman, Bear River and Gold Hill/Combie Canals). CALVIN represents the Bear River system from Camp Far West Reservoir to the confluence with the Feather River. The canal exports to DA 69 and DA 70 are modeled explicitly and offtake from a node upstream of Camp Far West. Inflows to this node represent the sum of inflows to Camp Far West Reservoir and net canal exports.

DWR no longer performs a depletion analysis for DA 68. Input for DWRSIM is developed from a modified HEC3 reservoir operation model. Figure I-11 summarizes the results from the model for the October 1921 – September 1993 period. The average projected inflow for this period is 353 taf. There is an additional accretion of 4 taf between Camp Far West and the Wheatland gage, approximately seven miles downstream. In DWRSIM, inflow from the Bear River is combined with inflows from DA 68 and DA 69 as part of IN32/37 to the Feather River.

Figure I-11. Bear River HEC-3 Model



Figures are the average annual flow (TAF)
Ref: Central Valley Future Water Supplies for Use in DWRSIM, DWR 1995

(m) DA 22, American River above Folsom Dam

The American River is the second largest tributary to the Sacramento River, contributing about 15% of the natural flow. It drains an area of 1,895 square miles stretching west from the Sierra Nevada to the City of Sacramento. It joins the Sacramento River at RM 60. Nineteen major reservoirs are located in the watershed with a combined storage capacity of 1,900 taf. Folsom Lake, located adjacent to the City of Sacramento, is the main storage and flood control reservoir on the American River. Upstream of Folsom, there is a combined storage capacity of 820 taf, 90% of which is accounted for by five reservoirs: French Meadows; Hell Hole; Loon Lake; Union Valley; and Ice House. French Meadows and Hell Hole Reservoirs on the Middle Fork of the American are owned and operated by Placer County Water Agency (PCWA). The agency provides water to agricultural areas within Placer County and wholesales treated water to municipalities. Loon Lake, Union Valley and Ice House reservoirs are operated by SMUD.

Currently, CALVIN represents only the lower watershed of the American River, downstream of Folsom Lake. Two rim flows in the model represent inflows to the lake from the combined North and Middle Fork and the South Fork. These are taken directly from DWRSIM input, inflows IN17 and IN8 respectively.

Local Water Supplies

The depletion analysis is used to develop local water supplies for DWRSIM. However, as previously discussed, these inflows contain both surface water and historic net groundwater pumping. Local water supplies for CALVIN are therefore based on output results from CVGSM. These supplies are calculated as the sum of direct runoff and groundwater gains and losses to the stream network contained within each depletion area. The following sections describe the local water supplies to each of seven depletion areas located within the floor of the Sacramento Valley. Local water supplies for DA 59 (East Side Streams) and DA 55 (the Delta), which span both the Sacramento River and San Joaquin River hydrologic regions, are described under the San Joaquin Hydrologic Region. The average annual water supplies for the seven floor regions are listed in Table I-12.

(a) DA 58 (CVPM Region 1)

Sacramento River, Shasta Dam to Red Bluff Diversion Dam Gage

DA 58 extends from Shasta Dam to the old river gage located just upstream of the Red Bluff Diversion Dam (RBDD). It includes the watersheds of Clear Creek and Cottonwood Creek on the right bank of the Sacramento River, and Cow Creek and Battle Creek on the left bank.

DA 58 lies downstream of DA 61 and DA 62. The depletion analysis removes the effects of Trinity River imports and storage in Whiskeytown and Keswick Reservoirs. DWRSIM inflows associated with DA 58 consist of IN3 (Clear Creek inflow to Whiskeytown Lake), IN4 (inflow to Lake Shasta), IN73 (Cottonwood Creek) and IN74 (local inflow/accretions). Depletions associated with DA 58 are added to YD76. However, they only occur during one month over the 73-year period.

The northern boundary of the CVGSM model is the Sacramento River at Keswick. The CVGSM rim flow for the Sacramento River at Keswick was compared to DWRSIM model results. The average annual flow for the two models for the 69-year period (water years 1922-1990) differs by only 10 taf or 0.2%. Within DA 58 CVGSM models Cow Creek, Battle Creek and Cottonwood Creek explicitly. The net average inflow for the 69-year period ending September 1990 from these streams and gains and losses to the Sacramento River totals 1,852 taf. For CALVIN, this inflow is split between inflow from Cottonwood Creek, estimated at 554 taf from DWRSIM (IN73) and the remainder of 1298 taf. The CVGSM estimation of local inflow/accretion is 10%, or 227 taf less than the net accretion/depletion represented in DWRSIM. It is considered that this is due to the inclusion of groundwater in the DWRSIM estimate.

(b) DA 10 (CVPM Region 2)

Sacramento River, Old Red Bluff Diversion Dam Gage to Ord Ferry

DA 10 covers the Sacramento Valley from the old RBDD gage to the Old Ferry gage located west of Chico, approximately eight miles downstream of the Sacramento's confluence with Stony Creek. Upstream depletion areas are DA 5 and DA 11 to the west, DA 58 to the north and DA 66 to the east. Streams within DA 10 include the Elder Creek, Thomes Creek and Stony Creek on the right bank of the Sacramento River and Antelope Creek, Mill Creek, Deer Creek and Big Chico Creek on the left bank.

Inflows to DA 10 represented in DWRSIM are Thomes Creek (IN75), Stony Creek (IN76) and Sacramento River accretions/depletions (IN77 and YD77). IN77 and YD77 represent the combination of DA 3 and DA 66 rim flows, plus Elder Creek from DA 5, plus DA 10 local water supplies. CVGSM explicitly models seven tributaries to the Sacramento River (Elder, Thomes, Stony, Antelope, Mill, Deer and Big Chico Creeks). Local water supply from these streams and gains and losses to the Sacramento River averages 199 taf annually for the 72-year period ending October 1993.

(c) DA 12 (CVPM Region 3)

Sacramento Valley Westside above Colusa Basin

DA 12 covers an area on the west bank of the Sacramento River stretching from Stony Creek in the north to Knights Landing Ridge Cut to the south. DA 12 has no upstream depletion areas but receives imports from DA 10 (Tehema-Colusa and Glenn Colusa Canals) and DA 15 (right bank diversions from the Sacramento River). Surface water runoff from the Coastal Range and irrigation return flows discharge into the Colusa Basin drain. This water is reused for irrigation before finally discharging into the Sacramento River as an inflow to DA 70 or flowing into Yolo Bypass through the Knights Landing Ridge Cut as an inflow to DA 65.

DA 12 is not modeled explicitly in DWRSIM. Diversions to meet demand are included in YD77 (diversion to DA 10) and YD30 (diversion to DA 15). In this region, CVGSM models the Glenn-Colusa Canal and Colusa Basin drain explicitly with accretions to both. The local water supply is the sum of runoff and gains and losses to these two channels. The net average annual inflow for the 72-year period is 445 taf.

(d) DA 15 (CVPM Region 4)

Sacramento River, Ord Ferry Gage to Knights Landing

DA 15 covers the reach of the Sacramento River from the Ord Ferry gage to Knights Landing immediately downstream of the Colusa Basin drain outflow. There are no major tributaries within the depletion area. For the purposes of the depletion analysis, DWR assumes that bank overflows to Butte City and spills over the Colusa, Moulton and Tisdale weirs stay within the depletion area and are part of the projected outflow. DWRSIM represents two external flows to this reach of the Sacramento River. YD66 represents a depletion. IN30 represents return flow and additional runoff from DA 10. CVGSM net gains to this reach of the Sacramento River average 64 taf over the 72-year period.

(e) DA 69 (CVPM Region 5)

Lower Feather River

DA 69 covers the lower Feather River from Oroville Dam to the mouth of the Feather at Verona. It is downstream of depletion areas: DA 14; DA 17; DA 67; and DA 68. In addition to the Feather River, DA 69 receives inflow from the Yuba River, Bear River, Butte Creek and Little Chico Creek. The flow from the Yuba corresponds to the projected outflow from DA 67 just above the Daguerre Point Diversion Dam. The flow from the Bear is the projected outflow from DA 68, which corresponds to the flow at the Wheatland gage. DA 14 is the drainage area for Butte Creek and Little Chico Creek and contributes to DA 69. DA 17 is the Feather River watershed upstream of Lake Oroville consisting of the North, Middle and South Forks. There are approximately 40 diversions along the Feather River. Four of the major diversions are from the Thermalito Afterbay: Western Canal; Richvale Canal; PG&E lateral; and the Sutter-Butte Canal.

For the depletion analysis, DWR assumes that all spills from the Sacramento River over flood weirs stay within the depletion area and are not exported. Spills into Sutter Bypass are thus accounted for in DA 15. Water is exported into the region from the left bank of the Sacramento River via drain RD1500. CVGSM models explicitly the Yuba, Bear, and Feather rivers and Sutter Bypass. The average annual local inflow is 648 taf for the 72-year period.

(f) DA 65 (CVPM Region 6)

Lower Yolo and Cache Creek Watershed

DA 65 covers the drainage area for Cache Creek below Rumsey and for Putah Creek below Monticello Dam. It is downstream of DA 16 and DA 24. Outflow from the region occurs via Yolo Bypass and the North Delta westside minor streams. The depletion area receives imports from DA 12 via the Knights Landing Ridge Cut and from DA 70 from the Sacramento River to supply the City of West Sacramento and agriculture on the right bank (Yolo Bypass Service Area) that requires supplies in addition to the Knights Landing Ridge Cut.

The region is not modeled explicitly in DWRSIM. Diversions from the Sacramento River are accounted for in YD44. Within the depletion area, CVGSM explicitly models Cache Creek (Reach 68), Putah Creek (Reach 69) and the Yolo Bypass (Reach 70). Local water supplies average 41 taf annually over the 72-year period.

(g) DA 70 (CVPM Region 7)

East Sacramento Valley, Bear to the American River

DA 70 covers the drainage area on the east bank of the Sacramento River between the Bear River to the north and the American River to the south. It includes the reach of the Sacramento River from Verona at the mouth of the Feather River to the confluence of the Sacramento and American rivers. It is bounded in the north by a stretch of the Bear River downstream of Camp Far West Reservoir. To the south, it includes the lower American River downstream of Folsom Reservoir but excludes the City of Sacramento service area. Analysis of the depletion area is complicated by a number of imports and exports. Exports include Sacramento River right bank diversions, PG&E South Canal and supplies to the City of Sacramento. Imports are made from the Bear, Feather and American Rivers. Diversions from the Bear River upstream of Camp Far West (DA 68) are via the Boardman Canal, Bear River Canal, Combie Canal and Tarr Ditch. Downstream of the reservoir (DA 69), water is imported via South Sutter Water District's Southline and conveyance canals and Camp Far West Irrigation District's South Canal. Additional imports are made from DA 69 from the left bank of the Feather River. In addition, Placer County Water Agency imports water from the North Fork of the American River (DA 22) to Auburn Ravine.

Local water supplies in DA 70 are modeled by inflow IN43 and part of outflow YD43 in DWRSIM. DWR (1995) suggests that this includes imports from the Bear River and Feather River. In CALVIN, imports into DA 70 are modeled. Imports from the North Fork of the American River are included in the inflow to Folsom Lake from the Auburn Reservoir site. From CVGSM, local water supplies for DA 70 average 83 taf. Instream flow requirements in the

American River downstream of Folsom are often critical to reservoir operations. Accretions and depletions to the American River downstream of Folsom have therefore been disaggregated from DA 70 local water supplies. These accretions have been taken from DWRSIM, IN9 and YD85. The CVGSM accretions to the American River have been subtracted from DA70 local water supplies.

Imports

The major import into the Sacramento Valley Hydrologic Region is from the Trinity River system from Lewiston Lake, via Clear Creek Tunnel, to Whiskeytown Lake. Other imports are minor in comparison and represent an additional 1% of total supply. These minor imports consist of imports from the North Lahontan region (Little Truckee and Echo Lake Conduit) and from the San Joaquin region (Sly Park).

Exports

The major exports from the Sacramento Valley Hydrologic Region occur at the Delta. Diversions into the California Aqueduct and Delta Mendota canal represent 96% of all exports. Other significant exports are via the Putah South Canal, North Bay Aqueduct, Contra Costa Canal, and Folsom South Canal. In addition, there are minor exports to the North Coast (North Fork Ditch), North Lahontan region (Moon Lake Ditch) and San Joaquin Valley (Folsom Lake diversions).

Flood Flows

Flood diversions are not calculated dynamically by CALVIN but are instead pre-processed and represented as a constrained diversion. In the Sacramento Valley, only flood discharges over the Freemont weir are represented explicitly. All other spills (e.g. to the Sutter Bypass) are retained within flows in the Sacramento River.

Freemont Weir

The Freemont Weir discharges flood flows from the Sacramento River into the Yolo Bypass. The weir is located on the left bank at the confluence of the Sacramento and Feather Rivers. Values estimated by DWR and those used in CVGSM are similar (1,626 taf cf 1,698 taf). DWRSIM diversion YD43, though labeled Freemont Weir, includes irrigation exports to DA 65, exports for the City of West Sacramento and depletions from DA 70. Data for CALVIN are taken from DWR hydrology 2020D09d. The projected spills are equal to the historic less a reduction to account for increased flood control upstream. After 1967, the projected spills are the same as historic. Water spilled to the Yolo Bypass is no longer available for export from the Delta.

SAN JOAQUIN RIVER HYDROLOGIC REGION

Introduction

The San Joaquin Valley is sub-divided into the San Joaquin River and Tulare Lake Hydrologic Regions. The San Joaquin River Hydrologic Region stretches from the Delta to the San Joaquin-Kings River divide in the south. It includes the Delta Eastside streams (Cosumnes, Dry Creek, Mokelumne and Calaveras) and the San Joaquin River watershed. The region covers an area of 15,950 square miles. The San Joaquin River rises in the southern Sierra Nevada. Its major tributaries all flow from the Sierra Nevada mountains: the Fresno, Chowchilla, Merced, Tuolomne and Stanislaus rivers. All of these rivers are regulated by storage reservoirs located in the Sierra foothills. In wet years, the San Joaquin River receives inflow from the Tulare basin via James Bypass and Fresno Slough. Precipitation on the west side of the Valley is relatively light so there are no major inflows from the Coastal range. The average annual runoff for the region is 7,933 taf (DWR 1993, Vol. 2, p).

CALVIN represents explicitly the inflows and major storage facilities of the six Sierra rivers and the Eastside streams. In addition to reservoir inflows, the model includes inflow from local runoff and surface-groundwater interaction. No Coastal range streams are modeled explicitly.

Climate

Moving from north to south, temperatures increase and precipitation becomes lighter. The west side of the valley is in the rain shadow of the Coastal Range and is relatively dry. On the east side, precipitation increases steadily with elevation. Average monthly precipitation for the San Joaquin Valley floor varies from 14 inches at Stockton to 8 inches at Mendota (USBR 1997).

Land Use

Land use affects runoff. DWR's depletion analysis represents CVPM Regions 10-13 by a single unit, DA 49. Projected land use values given in Table I-14 are taken from CVGSM input data. The total predicted agricultural area is 3%, or 39,145 acres larger than DWR's estimates. Similarly, the projected urban area is 3% or 7,100 acres larger. The total area of the four regions below is 2,947,000 acres.

Table I-14. San Joaquin River HR, Projected 2020 Land Use (acres)

Region	Undeveloped	Developed	Agriculture	Urban	Total
CVPM 10	203,377	455,221	430,221	25,000	658,598
CVPM 11	143,550	253,550	174,550	79,000	397,100
CVPM 12	91,730	244,397	200,397	44,000	336,127
CVPM 13	402,607	620,277	534,277	86,000	1,022,884

Source: USBR 1997

Agriculture in the San Joaquin River region is limited to the valley floor. It is modeled by six regions. CVPM Regions 10-13 are found entirely within the hydrologic region. CVPM Regions 8 and 9 span between the Sacramento and San Joaquin Regions. The major Central Valley cities in the region are Stockton, Tracy, Modesto and Merced. Other important communities are Lodi, Galt, Madera and Manteca.

Water Supplies

Table I-15 lists the external flows for the San Joaquin River Region that are represented by CALVIN. The majority of the rim flows are taken directly from DWRSIM's input files. However, for two flows, data were taken from other sources: the Delta Eastside Streams and the Tuolomne River. Local water supplies are based on CVGSM output.

<u>Rim Flows</u>

(a) Eastside Streams

The 'Eastside Streams' is a collective name for the streams that flow westward into the Delta region from the Sierra Nevada. They comprise the Cosumnes, Mokelumne and Calaveras Rivers and Dry Creek. DWRSIM represents these streams as a single inflow denoted 'Eastside Streams,' which enters at control point CP98. In CALVIN, these streams are represented individually so that the operation of storage facilities on the Mokelumne and Calaveras Rivers can be modeled explicitly - Pardee and Camanche Reservoirs on the Mokelumne River and New Hogan Lake on the Calaveras River.

The individual inflows from the Eastside Streams have been calculated from DWR's depletion analysis. DA 59, which is equivalent to CVPM Region 8, covers the Valley floor east of the Delta between the American River to the north and the Calaveras-Stanislaus divide to the south. DA 59 lies downstream of DA 25, DA 27, DA 29 and DA 32. The outflow from these four upstream depletion areas represents Cosumnes at Michigan Bar (DA 25); Dry Creek near Ione (DA 27); Mokelumne River above Camanche Reservoir (DA 29); and Calaveras above Jenny Lind (DA 32). It is assumed that agricultural and urban depletion in the upstream depletion areas is outside areas modeled by CALVIN, and therefore should be subtracted from the adjusted unimpaired flow. Analysis from the depletion analysis is available for the October 1921-September 1992 period. No data for October 1992-September 1993 are available from either the depletion analysis or SANJASM. USGS daily gage data was used to correlate annual flows in Cosumnes at Michigan Bar with those of Dry Creek, Mokelumne and Calaveras for the October 1921-September 1992 period. The linear regression coefficients were used to estimate the 1992/93 annual flows in Dry Creek, Mokelumne and Calaveras. These were disaggregated into monthly flows based on the average monthly distribution of flows between October 1921 and September 1992.

Cosumnes

The Cosumnes River is a tributary to the Mokelumne River. The rivers join near the town of Thornton in the Delta. The upstream watershed of 537 square miles is of low elevation, so that river flows are driven by direct runoff rather than snowmelt. Within the watershed, water is diverted from Jenkinson Lake for irrigation and municipal use by El Dorado Irrigation District and the City of Placerville. These diversions are part of the CVP Sly Park Unit. From the depletion analysis, the average projected outflow (1921-92) is 365 taf. The projected development within DA 25 and exports to DA 22 account for 25 taf.

Dry Creek

From the depletion analysis, the average projected outflow (1921-92) is 76 taf. The projected development within DA 27 accounts for 5 taf.

Table I-15. San Joaquin River HR, CALVIN External Flows (taf)

River	Description	Source	Av inflow 1922-90	Av inflow 1922-93
(a) Rim Flows				
Calaveras	Inflow to New Hogan Lake	Depletion	153	154
Cosumnes	Flow at Michigan Bar	Depletion	372	366
Dry Creek	Flow at mouth	Depletion	78	81
Mokelumne	Inflow to Pardee Reservoir	Depletion	694	681
Stanislaus	Inflow to New Melones Reservoir	DWRSIM (IN10)	1,071	1,057
Tuolomne	Cherry and Eleanor Creeks	SANJASM	439	441
	Inflow to Hetch Hetchy	SANJASM	753	747
	Local inflow to New Don Pedro Reservoir	DWRSIM (IN81)	622	617
Merced	Inflow to Lake McClure	DWRSIM (IN20)	928	922
Chowchilla	Inflow to Eastman Lake	DWRSIM (IN53)	70	69
Fresno	Inflow to Hensley Lake	DWRSIM (IN52)	85	84
San Joaquin	Inflow to Millerton Lake	DWRSIM (IN18)	1,698	1,681
Total rim flows			**6,963**	**6,900**
(b) Local Water Supplies				
Stanislaus	New Melones Dam to mouth gains	CVGSM	144	144
	losses	CVGSM	-1	-1
Tuolomne	New Don Pedro Dam to mouth gains	CVGSM	232	231
	losses	CVGSM	-2	-2
Merced	New Exchequer Dam to mouth gains	CVGSM	51	51
	losses	CVGSM	-18	-19
Fresno	Hidden Dam to mouth gains	CVGSM	7	7
	losses	CVGSM	-80	-79
Chowchilla	Buchanan Dam to mouth gains	CVGSM	24	24
	losses	CVGSM	-25	-24
Eastside Bypass	gains	CVGSM	157	153
	losses	CVGSM	-6	-6
San Joaquin	Friant Dam to Mendota Pool gains	CVGSM	47	47
	losses	CVGSM	-107	-107
	Mendota Pool to Merced gains	CVGSM	98	97
	losses	CVGSM	-82	-82
	Merced to Tuolomne gains	CVGSM	79	79
	losses	CVGSM	-32	-32
	Tuolomne to Stanislaus gains	CVGSM	20	20
	losses	CVGSM	-2	-3
	Below Stanislaus gains	CVGSM	282	283
	losses	CVGSM	-10	-10
	Total San Joaquin gains	CVGSM	526	526
	losses	CVGSM	-233	-234
Total local water			**776**	**771**
Total			**7,739**	**7,671**

Notes:
1 CVGSM accretion to Mendota Pool to Merced includes inflows from Deadman's Creek and Bear Creek.
2 CVGSM San Joaquin accretion Merced to Tuolomne includes 55 taf from Orestimba Creek.
3 CVGSM San Joaquin accretion Mendota Pool to Merced is the sum of CVGSM reaches 8,10,12,14 & 16.

Mokelumne

The Mokelumne is the largest of the Eastside Streams with a watershed of 661 square miles. In contrast with the other streams, the Mokelumne watershed originates high in the Sierra Nevada. Consequently, river flows are driven by snow melt. The Mokelumne flows into the San Joaquin River northwest of Stockton. Three major reservoirs on the Mokelumne regulate streamflow. Salt Springs Reservoir on the North Fork is owned by PG&E. Completed in 1963, it has a storage capacity of 141,900 af and is operated for hydropower. Pardee and Camanche Reservoirs are located on the mainstem and are owned by EBMUD. Pardee, the upstream reservoir, is operated for water supply. It has a storage capacity of 209,900 af (USBR 1997). Water is diverted from the reservoir to EBMUD's service area via the Mokelumne River Aqueduct. Camanche Reservoir, downstream of Pardee, is the larger reservoir with a storage capacity of 430,800 af. It is operated for flood control and to meet downstream instreamflow requirements. In addition to EBMUD, DWR (1968) identified 81 diversions along the Mokelumne. The largest diversion is at Woodbridge Dam for the Woodbridge Irrigation District.

From the depletion analysis, the average projected outflow (1921-92) is 348 taf. The projected development within DA 29 accounts for 6 taf plus an export (EBMUD and Jackson Valley ID from Pardee) of 326 taf (1921/22-1979/80 period only). There are insufficient data in the depletion analysis input to completely remove the effects (evaporation) of Pardee and Camanche Reservoirs. Instead, the inflow time series has been taken from USBR's San Joaquin Area Simulation Model (SANJASM). The average inflow for the 1921/22-1991/92 period is 684 taf. This compares with 674 taf for the combined DA 29 outflow and export. The small difference (< 2%) between the two flows is partly explained by reservoir evaporation.

Calaveras

The Calaveras watershed covers an area of 363 square miles east of Stockton in the Sierra foothills. The watershed is comparatively low so that runoff is almost entirely rain-driven. Nearly the entire annual flow occurs between November and April. Flows in the river are regulated by New Hogan Dam. The dam was constructed in 1963 by US Army Corps of Engineers, primarily for flood control, replacing a much smaller structure. New Hogan Lake has a storage capacity of 317,000. The dam is operated by Stockton East Water District.

From the depletion analysis, the average projected outflow (1921-92) 148 taf. The projected development within DA 32 accounts for 1 taf. There are insufficient data in the depletion analysis input to remove the effects of New Hogan Dam. Instead, the inflow time series has been taken from USBR's San Joaquin Area Simulation Model (SANJASM). The average inflow for the 1921/22-1991/92 period is 150 taf. The small (< 2%) difference between the two flows is partly explained by reservoir evaporation.

(b) Stanislaus River

The Stanislaus River drains 900 square miles of the Sierra Nevada. The average unimpaired runoff in the basin is approximately 1,200 taf/yr, with a range of 200 to 3,000 taf/yr (USBR 1997). Flows are largely driven by snowmelt, with peak flows occurring in May and June. New Melones Reservoir, constructed by USACE in 1978 regulates flow in the lower Stanislaus River. The structure replaced the original New Melones Dam built in 1924. The new reservoir has a capacity of 2.4 maf and is operated by USBR as part of the CVP. Tulloch Dam, located approximately 6 miles downstream of New Melones Dam, re-regulate power releases from New Melones. The Oakdale and the South San Joaquin irrigation districts are the principle downstream diverters. Diversions occur at Goodwin Dam, located approximately 1.9 miles downstream of Tulloch Dam. The diversion dam, built by the districts in 1912, also serves to re-regulate releases from Tulloch powerplant. Water impounded behind Goodwin Dam may be pumped into the Goodwin Tunnel for deliveries to Central San Joaquin Water Conservation District and the Stockton East Water District. Below Goodwin Dam numerous ungaged tributaries contribute flow to the lower reaches of the river. These streams flow intermittently and are usually dry by the late summer. Agricultural return flows and canal spills from land irrigated by both the Stanislaus and Tuolumne rivers enter the lower portion of the Stanislaus River. These surface sources, supplemented by groundwater accretion increase flows by nearly 30% along the 35 mile reach south of Goodwin Dam

(c) Tuolumne River

The Tuolomne River is the largest tributary to the San Joaquin River with a drainage area of 1,540 square miles. The unimpaired annual runoff varies dramatically from 400 to 4,600 taf, with an average of 1,950 taf/yr. Flows in the Tuolomne are regulated by New Don Pedro Dam, which was constructed in 1971 by Turlock ID and Merced ID assisted by the City and County of San Francisco. The two irrigation districts divert water downstream of New Don Pedro at La Grange Dam. The City and County of San Francisco operate several facilities in the upper watershed for water supply and power generation. O'Shaughnessy Dam constructed on the main stem at Hetch Hetchy Valley in 1923 provides M&I water. Releases are also made to meet in-streamflow requirements in the Tuolomne River. Upstream of Hetch Hetchy, the City and County operate Lake Eleanor and Cherry Lake for both hydropower and water supply. The City and County of San Francisco own 600 taf of storage within New Don Pedro Dam, which they use to meet their obligations to the district by exchanging stored water for water diverted at Hetch Hetchy.

In DWRSIM, the Tuolumne River is modeled from New Don Pedro Dam downstream. Inflow to the reservoir is represented by IN81 into CP81. CALVIN includes the upstream reaches of the Tuolomne River so that the operation of Hetch Hetchy Reservoir can be modeled explicitly. The reservoir supplies the City of San Francisco via the Hetch Hetchy Aqueduct. The inflows upstream of New Don Pedro Reservoir have been divided into three separate time series. Two new reservoirs, Hetch Hetchy Reservoir and a combined Eleanor/Cherry Reservoir, have also been added. Tuolumne River inflows enter into the Hetch Hetchy Reservoir, while the Cherry Creek and Eleanor Creek inflows are combined and entered into the combined reservoir. The third inflow, which represents the aggregation of all inflows downstream of the Hetch Hetchy, Eleanor, and Cherry Reservoirs, but above New Don Pedro Reservoir, enters the system into New Don Pedro Reservoir. Releases from either reservoir may flow either into New Don Pedro Reservoir or into the San Francisco urban demand node via the Hetch Hetchy Aqueduct. Flows from Lakes Cherry and Eleanor (which are diverted to the Hetch Hetchy Aqueduct) cannot be used for power generation at Holm Powerhouse. Diversions to the aqueduct from the aggergated reservoir are therefore discouraged by assigning a small penalty to the flow link. It is expected that flows from Lakes Eleanor and Cherry will only be used for San Francisco urban water supply during drought conditions.

The primary source of data used for the inflows into the Tuolumne River is the SANJASM 1996 inflow time series. These values cover the entire period, from October 1921 to September 1993, and are very similar to the unimpaired inflow values for the Tuolumne River provided by DWR. During each time period, the three inflow time series are divided such that their sum equals the SANJASM inflow for that time period. Flows entering the Hetch Hetchy and combined reservoirs are taken from the SANJASM 1195 inflow time series, which runs from October 1921 to September 1992. Inflows into Hetch Hetchy Reservoir from October 1992 to September 1993 are taken from CDEC. The station used is denoted TLN and is located near Hetch Hetchy Dam. All the data are in monthly time steps. On average, 1,801 taf/year are introduced into the system using the SANJASM inflows, compared to 1,527 taf/year introduced by DWRSIM and 1,802 taf/year introduced using DWR's unimpaired hydrology. The difference of 274 taf/year is only slightly greater than the average San Francisco diversion at Hetch Hetchy of 267 taf/year, as reported in Bulletin 160-93. The inflows for each upstream branch peak in May, reflecting snow melt.

From October 1921 to September 1992, for the vast majority of time periods, the combined inflow into the Hetch Hetchy and Eleanor/Cherry Reservoirs is less than the total Tuolumne River SANJASM inflow. In such cases, the inflow into New Don Pedro Reservoir has been determined by subtracting these inflows from the total inflow. There are, however, certain instances in which the inflows into the Hetch Hetchy and combined reservoirs are greater than the SANJASM inflow. In these instances, the Hetch Hetchy and Cherry/Eleanor reservoirs' inflows have been reduced so that their sum equals the total SANJASM inflow, and the third inflow has been assumed to be zero. These reductions are made so that each value loses the same percentage of its original value. Thus, the sum of the three inflows for each time period will equal the total SANJASM inflow for every time period. Since virtually all the cases where the adjustment is necessary occur during the summer months, when the flows are low, an average of only 2.6 taf/year has been subtracted from the Hetch Hetchy and Eleanor/Cherry Reservoirs' inflows.

From October 1992 to September 1993, the CDEC value entering Hetch Hetchy Reservoir is less than the total SANJASM inflow during each time period. Thus, the value entering Hetch Hetchy Reservoir equals the value from CDEC for each time period. The difference between this value and the total inflow is apportioned to the other two inflows according to the average percentage that enters each inflow from 1922 to 1992 as determined above.

Inflows into the Hetch Hetchy and the Cherry/Eleanor Reservoirs are taken from an older run of SANJASM than were the total SANJASM inflow. Thus, they may not correspond exactly, although a review of the data indicates a high degree of correlation. The final year of data is most likely the least accurate, because the CDEC data may not correspond exactly with the SANJASM data and because the time series for the other inflows were determined using an estimation method. Finally, all the inflow time series used represent total natural or unimpaired flow and, therefore, do not include the effects of diversions upstream from where the inflows are introduced into the model. This will tend to slightly exaggerate the inflows into each reservoir.

(d) Merced River

The Merced watershed covers an area of 1,273 square miles. The river originates near Tuolomne Meadows within Yosemite National Park. River flows are regulated by New Exchequre Dam and Lake McClure. The dam, completed in 1967, is owned by the Merced Irrigation District and operated for irrigation supply, flood control and power generation. McSwain Reservoir downstream of Lake McClure serves as afterbay for re-regulation. The Merced Irrigation District diverts some water at the Merced Falls Dam downstream of McSwain Dam. The district's main diversion point is at the Crocker Huffman Dam, which is downstream of McSwain. Flows are diverted into the district's Main Canal. From DWRSIM data, average annual inflows to Lake McClure over the October 1921 to September 1993 period are 922 taf.

(e) Chowchilla River

The Chowchilla River is a relatively small tributary of the San Joaquin River with a watershed of 236 square miles. The watershed is at low elevation so that flows are rain-fed. Historically, flows in the river were ephemeral with large flood flow in the winter and near zero summer flows. Flows in the river are now regulated by Buchanan Dam, completed in 1976 by USACE. Eastman Lake, formed behind the dam, has a storage capacity of 150,600 af (USBR 1997). Releases for water supply from Buchanan are supplemented by supplies from the Madera Canal. The Chowchilla River discharges into the Eastside Bypass. From DWRSIM data, average annual inflows to Eastman Lake over the October 1921 to September 1993 period are 69 taf.

(f) Fresno River

Similar to the Chowchilla River, the Fresno has a relatively small watershed at low elevation. It covers 237 square miles. Historically, the river was an ephemeral stream with winter flood flows and near zero summer flows. Flows in the Fresno River are now controlled by Hidden Dam, which was completed by USACE in 1975. Hensley Lake behind the dam has a storage capacity of 85,200 af. Releases for water supply from the dam are augmented by releases from the Madera Canal that discharge into the river three miles downstream of the dam. CVP contractors divert water from the river.

Both Buchanan Dam on the Chowchilla and Hidden Dam on the Fresno are operated in coordination with Millerton Dam on the San Joaquin. From DWRSIM data, average annual inflows to Hensley Lake over the October 1921 to September 1993 period are 84 taf.

(g) San Joaquin River

The starting point for the San Joaquin River in CALVIN is Millerton Lake, formed by Friant Dam. The dam was completed by USBR in 1941 and is part of the Friant Division of the CVP. Upstream of the dam, the river drains an area of 1,676 square miles. Several small hydropower facilities exist in this upper watershed with a combined capacity of 620,000 af (USBR 1997). These include Edison, Florence, and Huntington Reservoirs, Mammoth Pool and Shaver Lake. There are no important water supply diversions. Since completion of the dam, the majority of the river flow is diverted from Millerton Lake into the Madera and Friant-Kern Canals.

The average annual runoff for the San Joaquin Reservoir is 1,861,000 af (Friant Water Users Authority 1998). This compares with 520,500 af of total storage capacity in Millerton Lake. Due to the relatively small size of Millerton and its flood control function, it is necessary to draw the lake down to its minimum pool annually, and there is little opportunity for carry-over storage. From DWRSIM data, average annual inflows to Eastman Lake over the October 1921 to September 1993 period are 1,681 taf.

Local Water Supplies

Local water supplies are represented by a series of accretions and depletions along the San Joaquin River and its major tributaries. These accretions are taken from CVGSM.

(a) San Joaquin River between Friant Dam and Gravelly Ford

Flow above Gravelly Ford consists predominantly of reservoir releases with minor contributions from agricultural and urban return flows. Dam releases are usually restricted to those required to meet downstream riparian use.

(b) San Joaquin River between Gravelly Ford and Mendota Pool

The reach between Gravelly Ford and the Mendota Pool is approximately 17 miles in length. It is generally dry except during flood releases from Friant Dam. Historically, this reach of the river contributed much deep percolation to groundwater. Since the diversion of the San Joaquin River water to the Madera and Friant-Kern Canal, groundwater overdraft conditions have developed.

(c) San Joaquin River between Mendota Pool and Freemont Ford

Most of the water released from the Mendota Pool is diverted at or above Sack Dam for agricultural use. Between Sack Dam and the confluence with Salt Slough, the San Joaquin is often dry. Freemont Ford is situated just upstream of the river's confluence with the Merced. Salt Slough and Mud Slough are small low flow channels that enter the San Joaquin River just upstream of its confluence with the Merced River. The sloughs drain the west side of the Valley downstream of the Mendota Pool. In the summer, they primarily convey agricultural tailwater and subsurface drainage flows from the west side of the San Joaquin Valley. In the winter months, they also transport a limited volume of direct runoff. From DWRSIM data, average annual inflows are 161 taf, this may include agricultural drainage.

(d) San Joaquin River between Freemont Ford and Vernalis

Vernalis is generally considered the southern limit of the Delta. This lower reach of the San Joaquin is characterized by the right bank inflows from the Merced, Tuolomne and Stanislaus. The Vernalis water quality station is locate just downstream of the confluence of the Stanislaus and San Joaquin rivers. Inflows on the left bank include Orestimba Creek and Puerto Creek.

(d) San Joaquin River at Vernalis

Flows at Vernalis are primarily determined by the operation of the Friant, New Exchequer, New Don Pedro and New Melones Dams. Since the completion of New Melones Dam in 1978, monthly flows peak in March, averaging approximately 90,000 af with a minimum flow in October of 20,000 af (USBR 1997). Order 95-06 requires that USBR operate New Melones Dam to maintain conductivities below 0.7 mmhos/cm (~455 ppm TDS) between April and August and below 1.0 mmhos/cm (~650 ppm TDS) between September and March.

Comparison with CVGSM

Table I-16 contains a comparison between DWRSIM and CVGSM external flows. Flows downstream of reservoirs were taken from DWRSIM run 514. In general, CVGSM flows appear to be about 1.5% less. One source of discrepancy is the release from Friant Dam on the San Joaquin. The total local accretions and depletions are similar in the two models. However, there are obvious mismatches between their locations, especially along the San Joaquin River. It is thought that this is due to the different stream networks represented in the two models. The high CVGSM inflows downstream of the Stanislaus to the San Joaquin may be represented in DWRSIM by Delta precipitation. Between the Stanislaus and the Calaveras, there are Mormon, Duck, Little John, and Lone Tree Creeks. It is not known what the high DWRSIM accretion between the Merced and Tuolomne rivers represents.

Table I-16. San Joaquin River HR, Comparison of Average Annual Flows (taf)

Description	CVGSM	DWRSIM
	WY 1922-1990	WY 1922-1990
(a) Rim Flows		
Mokelumne d/s of Camanche Dam	422	
Cosumnes	334	
Dry Creek	79	
Calaveras d/s of New Hogan Dam	140	
Accretion	55	
Delta Eastside Streams Total	1,030	996
Stanislaus d/s of New Melones Dam	1,014	1,017
Tuolomne d/s of New Don Pedro Dam	1,449	1,458
Merced d/s of Exchequer Dam	890	885
Chowchilla d/s of Buchanan Dam	64	64
Fresno d/s of Hidden Dam	80	80
San Joaquin d/s of Friant Dam	282	313
Total Rim Flow	**4,809**	**4,813**
(b) Local Water Supplies		
Stanislaus below New Melones Dam	143	112
Tuolomne below New Don Pedro Dam	230	180
Merced below Exchequer Dam	33	83
Fresno below Hidden Dam	-73	0
Chowchilla below Buchanan Dam	-1	0
San Joaquin Friant Dam to Mendota Pool	-60	-59
San Joaquin Mendota Pool to Merced	171	166
San Joaquin Merced to Tuolomne	47	399
San Joaquin Tuolomne to Stanislaus	18	-4
San Joaquin below Stanislaus	272	0
San Joaquin Friant Dam to Delta	448	502
Total Accretion	**780**	**877**

Notes: 1 DWRSIM accretions from SANJASM

Imports

The major imports into the region are from the federal Delta-Mendota Canal and the joint federal-state San Luis Canal. Both canals import water from the Delta. In addition, flood releases from Pine Flat Reservoir on the Kings River are diverted north via James Bypass/Fresno Slough into the Mendota Pool on the San Joaquin River.

Exports

Exports from the San Joaquin Region are primarily from Millerton Lake on the San Joaquin River to the Tulare Basin via the Friant-Kern Canal. There are also minor exports downstream of Friant Dam. These include left bank diversions between Friant Dam (mile 268) and Mendota Dam (mile 209) and diversions from Fresno Slough and Fresno Slough Bypass. In the north, there are also several major exports for urban water supply. These include diversions from Pardee Reservoir into EBMUD's Mokelumne Aqueduct, water pumped from the Delta into the Contra Costa Canal, and water diverted by the City of San Francisco at Hetch Hetchy into the Hetch Hetchy Aqueduct.

TULARE LAKE HYDROLOGIC REGION

Introduction

The Tulare Lake Hydrologic Region forms an internally draining basin at the southern end of the San Joaquin Valley. It stretches from the San Joaquin River watershed south to the Tehachapi Mountains. It is enclosed by the Coastal Mountain range to the west and the Sierra Nevada range to the east. The region covers an area of 16,520 square miles. Hydrologically, the region is separated from the rest of the San Joaquin Valley by a raised sill in the valley trough formed by the Kings River alluvial fan.

The major rivers in the region are the Kings, Kaweah, Tule and Kern. Of these, the Kings and Kern are the most important. Each river rises high in the Sierra Nevada and discharges into lakes or sinks in the valley floor. Historically, the northern three rivers (Kings, Kaweah and Tule) discharged into the Tulare Lake Basin, a wetland area of 200,000 acres. The Kern River historically flowed into the Kern, Buena Vista and Goose Lakes. These natural wetlands have now been drained for agriculture. However, under wet conditions, the lakes may fill and water may flow from Kern Lake via Buena Vista Lake to the Tulare Lake through a series of sloughs. The total average runoff for the region is 3,314 taf (DWR 1993). Four dams (Pine Flat, Terminus, Success, and Isabella) built by the Army Corps of Engineers now regulate flow in the major rivers.

Climate

The valley floor has mild springs followed by hot, dry summers. Winters are typically cold; frost is not uncommon. Average annual precipitation for the valley floor is approximately six inches compared to reference crop evapotranspiration of 52 inches.

Land Use

The Tulare Lake Region is divided into five PSAs. The Western Uplands PSA and the Uplands PSA of the Sierra foothills are not included in CALVIN. The projected cropped acreage for these two regions is 8,200 acres, all located within the Uplands PSA. The projected 2020 agricultural land area for the three PSAs in the valley floor is 2,871,700 acres (DWR 1998). For modeling purposes, the Tulare Basin is divided into seven units: CVPM 14 to 21. The main population centers are Fresno and Bakersfield. In addition, there are many small but rapidly growing agricultural communities on the east side of the valley, predominantly in the Visalia-Tulare area.

Water Supplies

Agriculture is the main consumer of water, accounting for 95% of water use within the region. DWR (1993) estimates that at the 1995 level of development, 33% of supply is from local surface water supplies and 19% from groundwater. Imports account for the remaining 48%. The Sierra Nevada is the source of all major surface water inflow to the region.

Table I-17. Tulare Lake HR, Projected 2020 Land Use (acres)

Region	Undeveloped	Developed	Agriculture[1]	Urban[2]	Total[2]
CVPM 14	124,776	531,800	521,300	10,500	656,576
CVPM 15	245,727	639,400	604,700	34,700	885,127
CVPM 16	59,828	247,700	96,900	150,800	307,528
CVPM 17	91,681	275,500	237,900	37,600	367,181
CVPM 18	161,858	721,800	641,500	80,300	883,658
CVPM 19	525,932	262,100	255,700	6,400	788,032
CVPM 20	197,679	222,000	204,100	17,900	419,679
CVPM 21	234,186	412,100	310,600	101,500	646,286
Total	1,641,667	3,312,400	2,872,700	439,700	4,954,067

Notes: 1 DWR Bulletin 160-98 supporting data
2 CVGSM cvpeis\disc2\naa\cnjcrop.nea

The four principal rivers are Kings, Kaweah, Tule and Kern. All four rivers flow westward to terminate in the valley floor. Only in extremely wet years are water levels sufficiently high that water spills northward into the San Joaquin River.

Rim Flows

Rim flows for the Tulare Basin are the Kings River inflow to Pine Flat, Kaweah River inflow to Lake Kaweah, Tule River inflow to Lake Success and Kings River inflow to Lake Isabella. Several sources of data were collected to produce a time series of rim flows for 1921-93, including CVGSM, USGS, CDEC and USACE. Streamflows have been significantly regulated since the construction of four principal dams by the USACE for flood control and water supply. Pine Flat Dam on the Kings was completed in 1954, Success Dam on the Kaweah in 1962, Terminus Dam on the Tule in 1961, and Isabella Dam on the Kern in 1953.

(a) Kings River

The upper watershed of the Kings River originates in the Sierra Nevada west of Mt. Whitney and extends westward to Pine Flat Dam. It covers a drainage area of 1,545 square miles. The North, Middle and South Fork of the Kings River converge upstream of the dam. Downstream the river crosses the Friant-Kern Canal and then becomes braided, forming many channels upon reaching the Kings River alluvial fan. At Crescent Weir, flood flows are diverted northward into the North Fork/Fresno Slough, which eventually discharges into the Mendota Pool. The South Fork of the Kings River drains into the Tulare Lake Bed. Upstream of Pine Flat Dam, there are four dams on the North Fork that are used for hydropower generation.

Flows in the Friant-Kern Canal can be discharged via the wasteway into the river for subsequent irrigation diversions. There are 14 agricultural diversions on the main stem between Pine Flat Dam and Crescent Weir. There is one diversion from the North Fork/Fresno Slough and another eight on the South Fork.

(b) Kaweah River

The upper watershed of the Kaweah upstream of Terminus Dam covers an area of 561 square miles and includes the North, Marble, Middle, East and South Forks of the Kaweah. There are three hydropower diversions above Lake Kaweah. All diversions return to the river. Downstream of the dam, there are 12 agricultural diversions.

(c) Tule River

The upper watershed of the Tule River upstream of Terminus Dam is 393 square miles and includes the North, Middle and South Forks. Above Lake Success, there are two hydropower diversions that return the majority of flow to the river and several minor agricultural diversions. Downstream of the dam, there are eight agricultural diversions. Between 1961-1977 the diversions totaled 500-21,400 af/yr (USBR 1997).

(d) Kern River

The Kern River is the most southerly of the major tributaries to the San Joaquin Valley. The watershed of 2,410 square miles extends south-west from the Sierra range around Mt. Whitney to the city of Bakersfield. Snowmelt during the late spring and summer months contributes about 90% of the annual rim flow. The Kern is regulated by Isabella Dam, completed by USACE in 1954. Isabella Lake receives inflow from the main stem and South Fork of the Kern River. The watershed upstream of the dam is 2,074 square miles

Four power plants are located on the Kern River. One plant is located upstream of Isabella Dam on the main stem. The other three are located downstream. There are 14 agricultural diversions from the Kern River. Between 1961-1977, these ranged between 175 taf and 2,000 taf with an average of 427 taf/yr (USBR 1997). The Friant-Kern Canal terminates at the river downstream of Isabella Dam. Between 1961-1977, the canal discharged an average of 18,000 af/yr into the river.

Data Analysis

Input data for CVGSM in the Tulare Lake region consist of rim flows downstream of the major storage reservoirs. These rim flows are based on historical records (KRWA, KRCD) as follows:

- Kings River: total available flow for distribution, i.e., the sum of Pine Flat Dam releases, inflow from Mills Creek and Hughes Creek and inflow from the Friant-Kern Canal Kings River wasteway (source: KRCD) ;

- Kaweah River: flow equals the sum of Kaweah River flows, plus upstream diversions and the flow in Dry Creek (source: KRWA);

- Tule River: flow equals the Tule River near Porterville, (USGS 11203500, WY 1922-60), Tule River below Success, (USGS 11204900, WY 1961-1990);

- Kern River: flow equals the Kern River near Bakersfield, (USGS 1194000, WY 1922-68), WY 1969-90, taken as 1st Point Flow (source: KRWA annual reports);

- Friant-Kern Canal wasteway delivery to the Tule River (source: USBR Fresno Office field records 1970-90, 1922-69 unavailable); and

- Friant-Kern Canal wasteway delivery to the Kaweah River (source: USBR Fresno Office field records 1970-90, 1922-69 unavailable)

It is assumed that deliveries from the Friant-Kern Canal wasteways reflect the contribution of direct runoff that enters the canal from upstream watersheds and not operational spills. For the Tule and Kaweah Rivers, these contributions are small, 3 taf and 424 taf, respectively.

CDEC monthly flow data were obtained for stations on the Kings, Kaweah and Kern Rivers (Table I-18). These data are from stations operated by USACE. Both the measured and 'full natural flow' data are available for each station. No data were available for the Tule River before 1994. USACE data are either reservoir inflows or natural flows. The USACE data sets begin in the 1950s. USGS data are stream gage data. USGS gage sites exist upstream of storage reservoirs but these data have not been used.

USACE estimates of reservoir inflows have been used where available. Prior to the construction of the reservoirs, CDEC data have been used. It is assumed that there is and will be no significant diversion of water upstream of the major storage reservoirs or major changes in land use, so that the historic unimpaired flow equals the projected 2020 flow. There are two hydropower reservoirs upstream of Pine Flat Dam on the Kings River. It is assumed that the effects of re-regulation for power generation is minimal.

The Kern and Kaweah Rivers data from USACE show much higher inflows in the 1950s compared to CDEC, USGS and CVGSM data. However, the CDEC and USACE reservoir inflow data were found to be extremely well correlated (>0.99) for the years 1960 through 1993. CDEC data were used for 1921-1960, USACE data for 1960-1993. The various sources of data are summarized in Table I-18.

Table I-18. Data Sources for Streamflows, Tulare Lake HR

River	Source	Station Name	Stn No.	Period of Record	Comments
Kings	CDEC	Kings R. – Pine Flat	KGF	01/1905-present	Full natural flow
Kings	USGS	Piedra Kings R. below Pine Flat Dam	11222000 11221500	10/21-09/59 01/54-10/90	Historic gage data
Kings	USACE	Kings R. – Pine Flat		10/59-present	Natural flow
Kaweah	CDEC	Kaweah R. - Terminus	KWT	01/1905-present	Full natural flow
Kaweah	USGS	Kaweah R. below Terminus Dam	11210950	10/61-09/90	Historic gage data
Kaweah	USACE	Inflow to Terminus		10/53-present	Reservoir inflow
Tule	USGS	Tule R. near Porterville	11203500	11/01-09/60	Historic gage data
Tule	USACE	Tule R. – Success		10/59-present	Reservoir inflow
Kern	CDEC	Kern R. - Bakersfield	KRB	01/1905-present	Full natural flow
Kern	USGS	Kern R. near Bakersfield	11194000	10/1893-09/76	Historic gage data
Kern	USACE	Kern R. - Isabella		01/59-present	Reservoir inflow

Available unimpaired or natural flows on the Tule River were not found for years prior to 1960. Flows were therefore estimated from regression analysis with the Kings, Kern, and Kaweah Rivers. For the analysis, CDEC data were used for 1921-1960 and USACE data from1960-1993.

Figure I-12. Kings River Flows

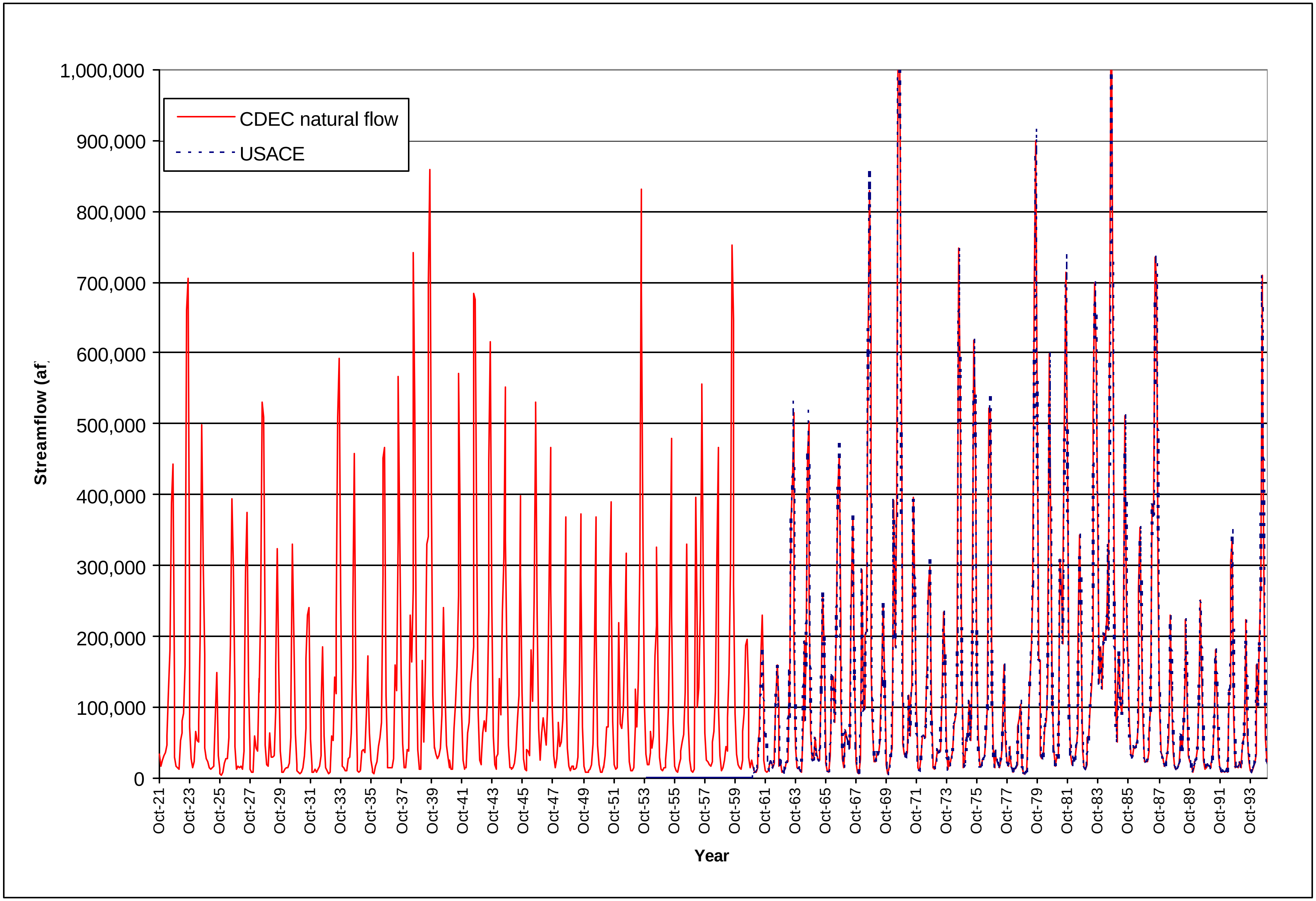


Figure I-13. Kaweah River Flows

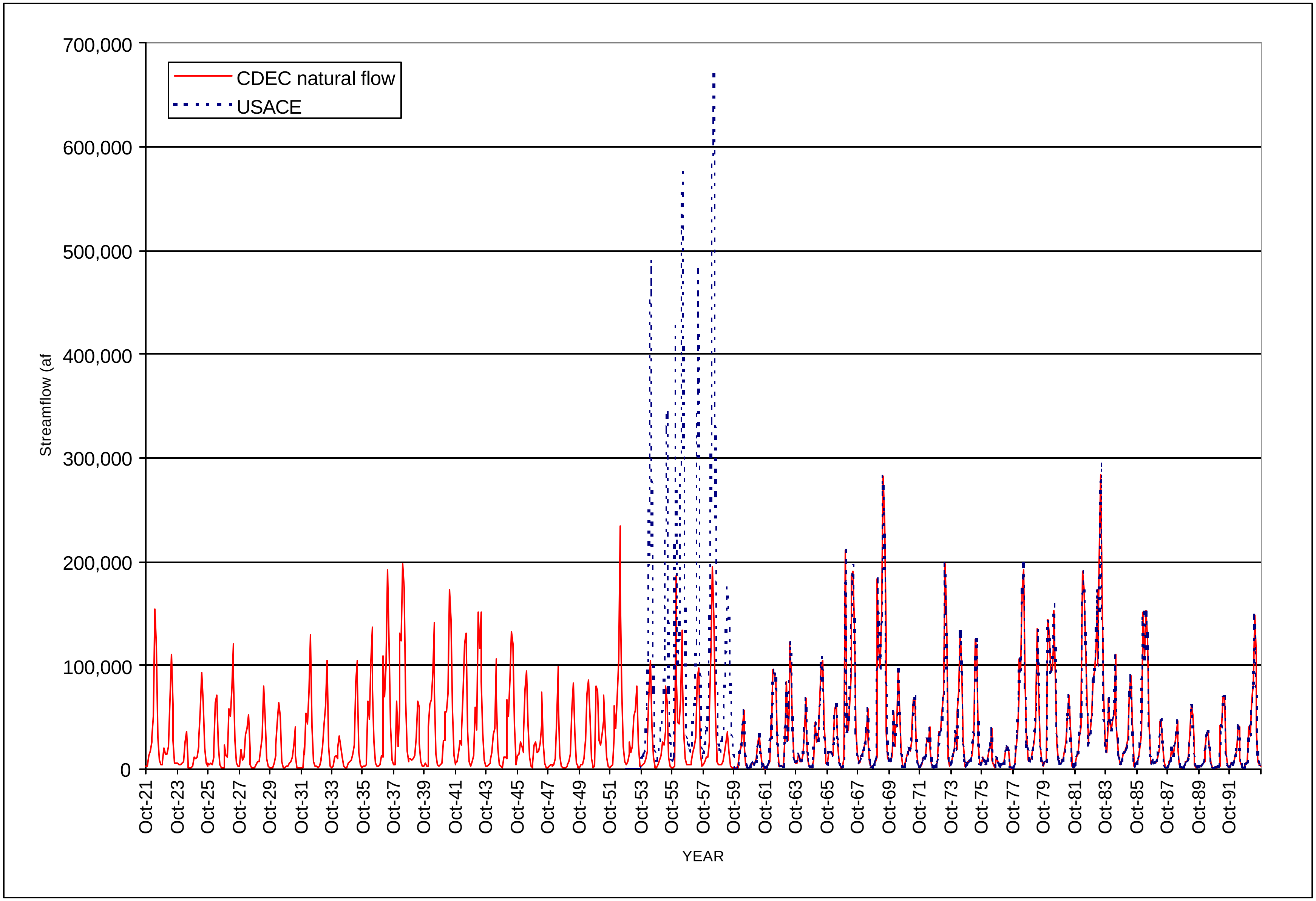
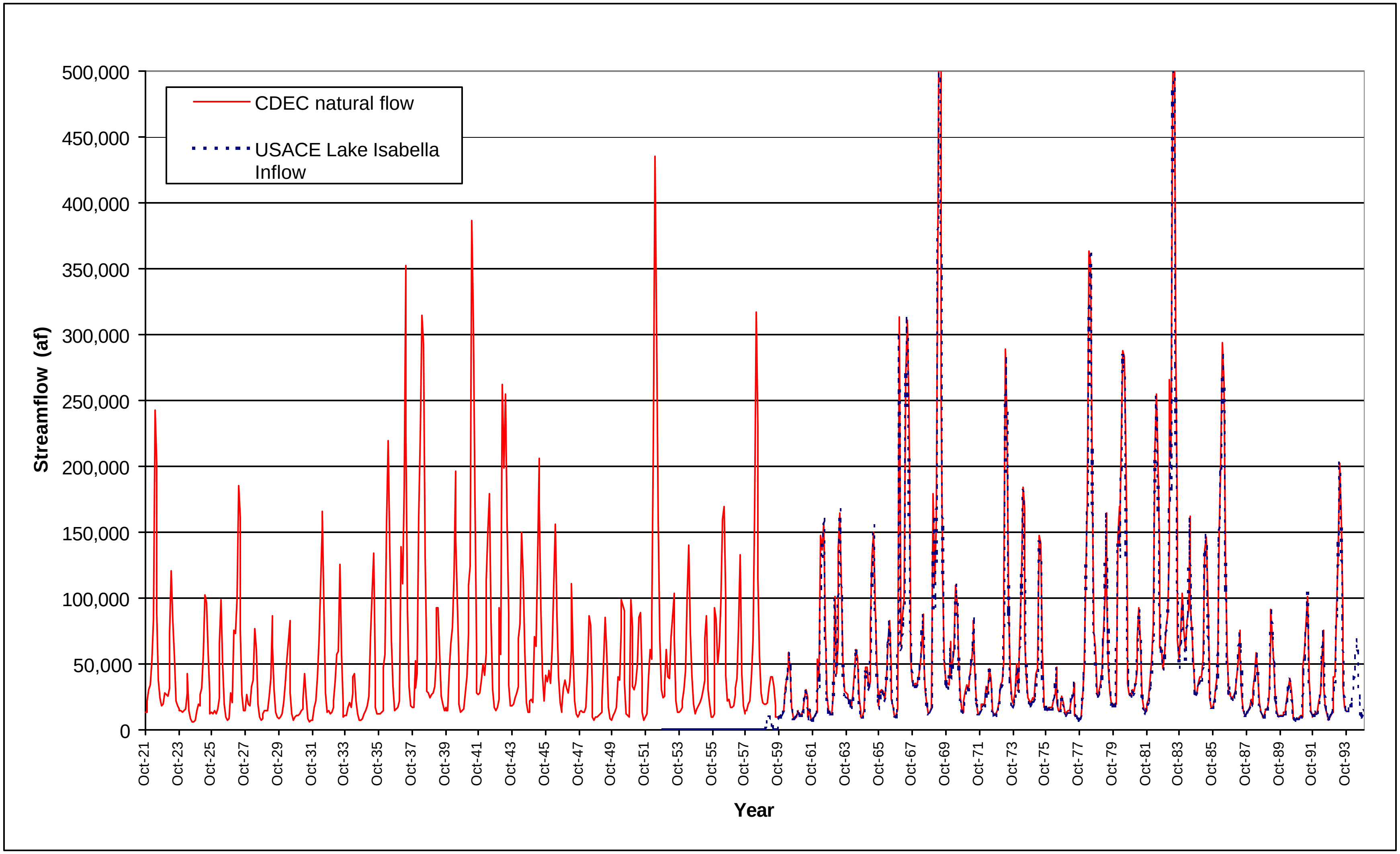


Figure I-14. Kern River Flows



The regression equation predicted negative flows for the Tule River for ten months during the 1921-59 period. Negative values were predicted for the months of May, June, and September. When this occurred, different combinations of statistically significant variables were used to attempt production of only positive flows. If it was not possible to predict only positive flows, the negative values were replaced with zeroes.

Table I-19. Tule River, Regression Analysis

Month	Relationship equation	r^2	Corr-elation	-ve predicted values
	.55Kaweah - 132	0.98	0.90	
	1.08Kaweah - .24Kings + 2805	0.96	0.96	
	1.18Kaweah - .27Kings + 2530	0.98	0.95	
	.86Kaweah + .08Kern - .2Kings + 1977	0.97	0.66	
	.62Kaweah + .06Kern - .12Kings - 1568	0.96	0.86	1928, 1934, 1959
	.28Kaweah + .09Kern - .06Kings - 1796	0.97	0.92	1924, 1959
	.28Kaweah - .03Kings + 324	0.94	0.96	
	.18Kaweah + 115	0.89	0.92	
	.14Kaweah + .1Kern - .03Kings - 522	0.90	0.78	1924, 1931
	.27Kaweah + .1Kern - .04Kings - 567	0.92	0.88	
	.44Kaweah + .1Kern - .05Kings - 454	0.97	0.99	
	.57Kaweah + .12Kern - .06Kings - 1361	0.99	0.97	

Table I-20. Tulare Lake HR, Average Annual Flow (TAF)

River		Source	Inflow 1921-90	Inflow 1921-93
Kings	Inflow to Pine Flat reservoir	CDEC, USACE	1602 (1711)	1594
	SW Accretion below Pine Flat dam	CVGSM	236	
	GW depletion below Pine Flat dam	CVGSM	-249	
Kaweah	Inflow to Lake Kaweah	CDEC, USACE	421 (414)	416
	SW Accretion below Terminus dam	CVGSM	123	
	GW depletion below Terminus dam	CVGSM	-20	
Tule	Inflow to Lake Isabella	CDEC, USACE	134 (111)	132
	SW Accretion below Isabella dam	CVGSM	256	
	GW depletion below Isabella dam	CVGSM	-105	
Kern	Inflow to Lake Success	CDEC, USACE	692 (686)	684
	SW Accretion below Success dam	CVGSM	95	
	GW depletion below Success dam	CVGSM	-205	
Fresno Slough	SW Accretion	CVGSM	49	
	GW depletion	CVGSM	-20	
Total			3009	
Notes: Rim flows used in CVGSM are shown in parenthesis				

The total of 2,808 taf compares with a value of 2,641 taf given by DWR in Bulletin 160-93 as the available water from local supplies. This latter figure is interpreted as the average annual yield. Flood water from the Kings River flows either northward via the North Fork into the San Joaquin River or south into the Tulare lakebed flooding agricultural land. Excess runoff from the Kaweah and Tule Rivers also discharge into the lakebed. Since 1977, flood water from the Kern River can be diverted into the California Aqueduct via the Kern river intertie. DWR estimates that the average annual runoff for the region is 3,314 taf.

The total estimated inflow to the four reservoirs is 2,849 taf (1921-90). This compares to a total reservoir release input to CVGSM of 2,939 taf. The largest discrepancy is for the Kings River, where the reservoir inflow used in CALVIN is 110 taf less than the estimated release used in CVGSM. More work has to be carried out to solve this apparent problem.

Local Water Supplies

No depletion analysis has been conducted for the Tulare Basin. It is, therefore, not possible to distinguish between rim flows from upstream depletion areas and local water supplies originating from depletion areas within the boundary of the model. For the Tulare Basin, rim flows are taken as the four major river inflows on the Kings, Kaweah, Tule and Kern, upstream of the foothill reservoirs. The contribution of other streams and runoff originating outside the model area is included as part of the local supply. This includes St. Johns River, Dear Creek, White River and Poso Creek, which all originate in the Sierra Nevada foothills and flow west into CVPM Regions 16 to 21, crossing the Friant-Kern Canal. Inflow from the Tehachapi Mountains includes Caliente, El Paso and Tejon Creeks. There is minor runoff from the Coastal Range. Most of the runoff from small streams percolates to groundwater. Poso Creek, Calente Creek, Tejon Creek and El Paso Creek contribute approximately 45,000 af/yr to groundwater recharge.

The CVGSM stream network explicitly represents the Kings, Kaweah, Tule and Kern Rivers and the Fresno Slough. In the CVGSM representation, flows in the Kaweah River and South Fork of the Kings River discharge into the terminal node of the Tule River, from where any downstreamflow is removed from the model to the sink. Similarly, any remaining flow at the downstream end of the Kern River is removed from the model. There is no representation of the Kern-California Aqueduct intertie, flood flows from the Kings River to the Mendota Pool, nor the Tulare Lake. All direct runoff and groundwater gains and losses are attributed to the stream network. This includes inflow from a series of small watersheds that lie outside the CVGSM model boundary, but whose influence is accounted for using a rainfall-runoff model.

The local water supplies for CALVIN are taken as the sum of direct runoff and groundwater gains to the CVGSM network. The average annual flow is given in Table I-20. The net annual average contribution is 160 taf. Inflows from Mill Creek and Hughes Creek to the Kings River is included in the CVGSM inflow to the Kings River. These inflows should therefore be added to CALVIN.

Imports

Federal CVP water is imported into the region from the San Joaquin River at Millerton Lake via the Friant-Kern Canal, and from the Delta via the Delta Mendota Canal and Mendota Pool. CVP water is delivered from the Delta via the California Aqueduct as part of the Joint-Use facilities with the CVP San Luis Unit. Additional SWP water is imported from the California Aqueduct. Current average water supplies are 2,700,000 af from the CVP and another 1,200,000 af from the SWP.

Exports

Excess water from the Kings River flows northward through Fresno Slough into the Mendota Pool. This water may be used to meet demands at Mendota. Under native conditions, the Kern River discharged into the trough of the valley, creating the Buena Vista and Kern Lakes. These lake beds have been reclaimed for agriculture. Only during flood conditions does water reach the valley trough. This flood water is approximately 20,000 af/yr and can be exported south from the region via the Kern River intertie with the California Aqueduct.

SOUTH LAHONTAN HYDROLOGIC REGION

Introduction

The South Lahontan Hydrologic Region lies on the east side of the Sierra Nevada mountains. It stretches from the Bodie Hills, north of Mono Lake, south of the Mojave Desert. It has no natural outlet and consists of desert valleys and dry lakes. Most of the runoff in the region flows from the Sierra Nevada and the White-Inyo Mountain ranges in the northwest. Owens Valley is located in the north of the region. Death Valley and a series of internally draining salt basins lie to the southeast. In the south of the region, the Mojave River flows east from Victorville through the Mojave Desert.

The region is important in the CALVIN model due to the existence of the Los Angeles Aqueduct. The aqueduct taps the water supplies of the Mono Basin and Owens Valley. Providing up to 550 taf/yr to the City of Los Angeles, the LAA has been and will continue to be one of the most important sources of water for Southern California.

Climate

Temperature and precipitation vary considerably with altitude. Average annual precipitation for the region is eight inches. Average annual precipitation in the region's valleys is typically in the range of 4-10 inches. For the City of Bishop, located in Owens Valley, average annual precipitation is 5 inches compared with a reference crop evapotranspiration of 68 inches (CIMIS station #35).

Land Use

Agriculture in the region is limited accounting for only one percent of the land area. Table I-21 gives DWR's land use estimates by PSA. Multiple cropping is not practiced so that the cropped acreage is equal to the land area. By far, the most important agricultural area is the Mono-Owens PSA. It accounts for nearly 30,000 acres of irrigated land, primarily alfalfa and pasture. The most significant change is the rapid urbanization in Antelope and Mojave River Valleys. The main population centers are located in Los Angeles and San Bernardino Counties in the southwest.

Table I-21. South Lahontan HR, Projected Land Use (acres)

PSA	1995 acreage	2020 acreage	Percent change
Mono-Owens Area	28,260	29,290	4
Death Valley	2,000	1,890	-6
Indian Wells Area	2,950	2,010	-32
Antelope Valley	12,340	900	-93
Mojave River	15,330	11,470	-25

Source DWR Bulletin 160-98 supporting data

Water Supplies

Table I-22 below gives DWR estimated water supplies for the year 2020.

Table I-22. South Lahontan HR, Water Supplies (taf)

Supplies	2020 average	2020 drought
Surface Water	437	326
Groundwater	248	296
Recycled/desalted	27	27
Total	712	649

Source: DWR 1998, p9-17

Local Water Supplies

No local surface water supplies, other than the Owens River, are represented in CALVIN. The Mojave River is an ephemeral stream and no significant volumes are diverted, although the river does recharge the groundwater.

Imports

Water is imported into the region via the East Branch of the California Aqueduct. SWP water is delivered to five SWP contractors within the region.

Exports

The major export from the region is from the Mono-Owens region via the Los Angeles Aqueduct to supply the City of Los Angeles. The initial pipeline constructed in 1913 had a capacity of 480 cfs (313 taf/yr). A second aqueduct completed in 1970 added 300 cfs (195 taf/yr) capacity. DWR estimate the combined capacity to be 550 taf/yr (DWR 1998, p9-17). The first aqueduct begins at Lee Vining on the west side of Mono Lake. The second aqueduct offtakes from Haiwee reservoir. Both pipelines terminate at the Los Angeles Reservoir in the South Coast Region. There are a total of eight reservoirs along the pipeline to store and regulate flow. The combined capacity totals 323 taf (DWR 1998, p9-17). Lake Crowley and Lake Grant at the head of the system are the largest, with a joint capacity of 230 taf.

Litigation has affected the operation of LAA.

- After 25 years of legal argument, agreement was reached between LADWP and Inyo County in 1997 on long-term management of groundwater supplies. Groundwater is pumped to supply the second aqueduct.
- In 1994, SWRCB amended LADWP’s water licenses so as to establish instreamflow requirements for four streams in the Mono Basin, from which the agency diverts water and prohibits or restricts exports from the Mono Basin so as to protect water levels in Mono Lake.
- In 1997, the City of Los Angeles was ordered to implement dust control measures at Owens Lake. The original plan called for 51 taf/yr to permanently flood part of the lake and plant grass and irrigate another part. This plan is currently under review.

The inflows from the Mono Basin have been aggregated into four different inflows along four distinct sub-regions in the South Lahontan Region[2].

Table I-23. Mono Basin Inflows

Region	Major Streams in Aggregation	Av annual inflow 1934-1993 (taf/yr)
Mono Basin	Lee Vining, Walker, Parker, Rush Creeks	123
Long Valley (Grant Lake to Long Valley Reservoirs)	Hot, Glass Creeks and Upper Owens River	109
Long Valley to Tinemaha Reservoirs	Convict, McGee, Hilton, Crooked, Rock, Pine, Horton, Bishop, North Fork Bishop, Big Pine, Tinemaha, Baker, Birch, Red Mountain Creeks and Middle Owens River	198
Tinemaha to Haiwee Reservoirs	Independence, Sheperd, Georges, Hogback, Taboose, Goodale, Sawmill, Georges, Lone Pine, Tuttle, Cottonwood, Braley, Ash Creeks, and Lower Owens River	103

Sources: Vee Miller, Los Angeles Department of Water and Power (Data)
LADWP, *Surface Water Course Schematic: Mono Basin Area*, April 1993.
LADWP, *Surface Water Course Schematic: Long Valley Area*, January 1993.
LADWP, *Surface Water Course Schematic: Round Valley Area*, January 1993.
LADWP, *Surface Water Course Schematic: Laws Area*, January 1993.
LADWP, *Surface Water Course Schematic: Bishop Area*, January 1993.
LADWP, *Surface Water Course Schematic: Big Pine Area*, January 1993.
LADWP, *Surface Water Course Schematic: Tinemaha to Haiwee Area (1-2 and 2-2)*, January 1993.

Mono Basin diversions are limited by instream flow requirements and the need to maintain a specified Mono Lake elevation (see Appendix F: Environmental Constraints). DWR (1998, p9-21) estimates LADWP diversions will be limited to about 31 taf/year under these requirements.

Figure I-16 shows the representation of the Owens Valley within CALVIN. The inflows of 'Long Valley to Tinemaha' and 'Tinemaha to Haiwee' have been aggregated into 'Long Valley to Tinemaha.' Data were provided by the LADWP for water years 1934-1993. Regression analysis was used to extend the data back to 1921. The analysis was based on CDEC values for the Upper Owens River that are available for the period January 1913 - October 1992. 'Long Valley to Tinemaha' was extended by using a linear regression of the annual totals. The annual totals were then converted to monthly values by multiplying each value by the average monthly distribution of 'Long Valley to Tinemaha.'

Agricultural water demands were modeled as fixed annual deliveries using 2020 land use projections and the corresponding water requirements for each crop (a diversion of 151 taf/yr). If these monthly demands exceeded water supply availability, the demands were reduced to match the water supply availability. This occurs in dry years since the peak Owens Valley water supply is June, while the peak Owens Valley agricultural water demand for alfalfa and pasture is February through March.

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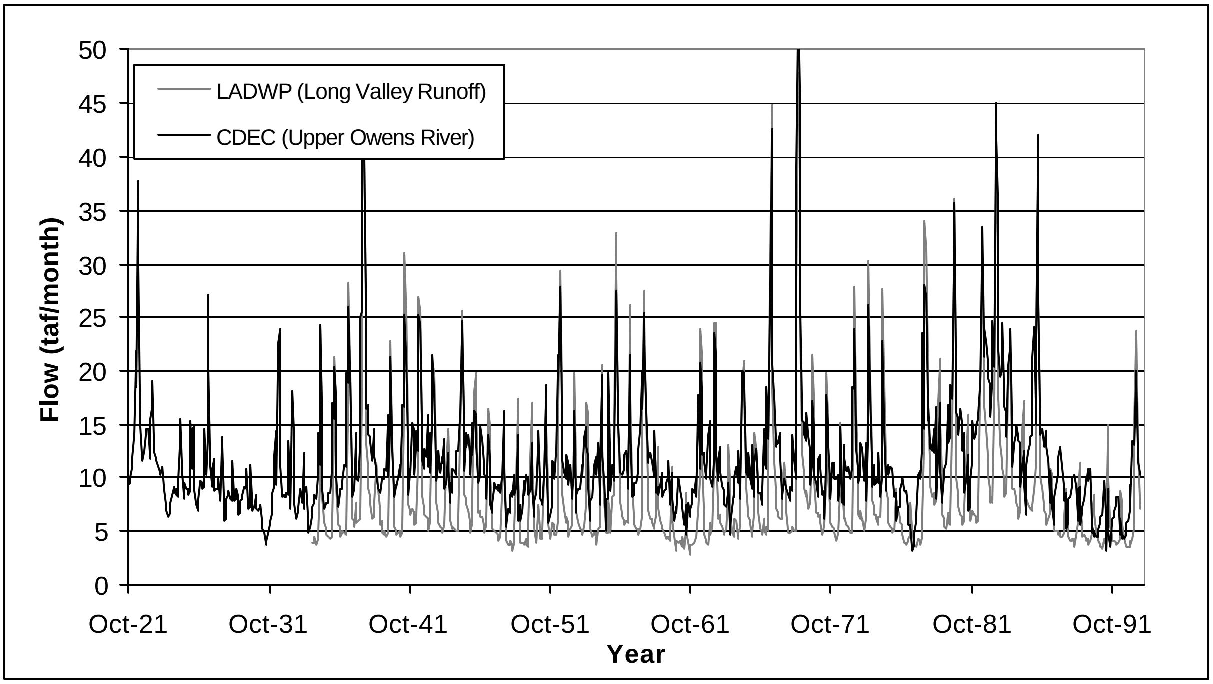
[2] As recommended by Bill Hasencamp, former chief hydrologist for Los Angeles Department of Water and Power

Figure I-15. Upper Owens Valley Monthly Flows



Water Rights and Contractual Agreements

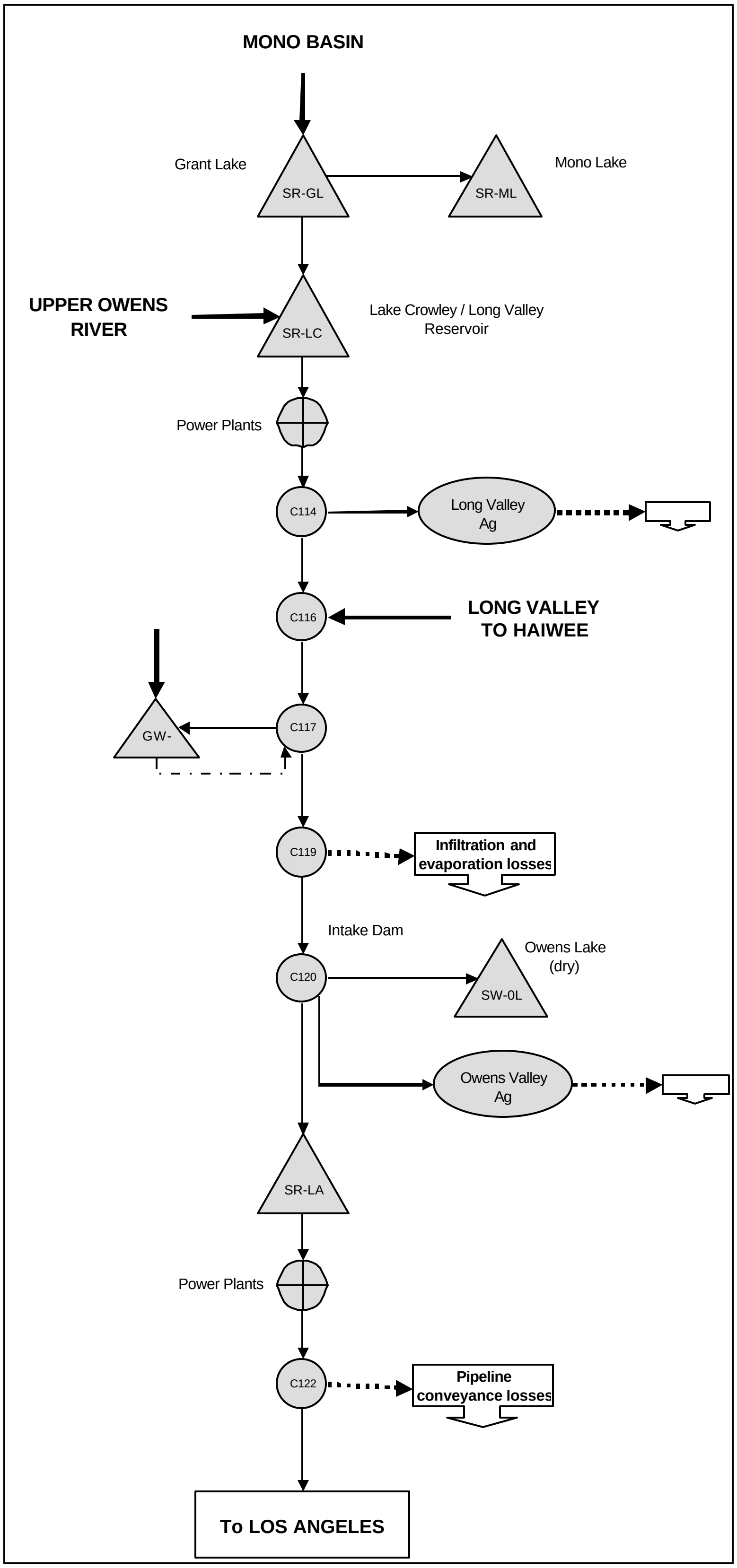
Table I-24 lists the SWP contractors within the region and their annual entitlements. Part of Mojave WA service area extends into the Colorado River Hydrologic Region.

Table I-24. South Lahontan HR, SWP Contractors

Contractor	Entitlement (taf/yr)
Antelope Valley-East Kern WA	138.4
Crestline-Lake Arrowhead WA	5.8
Littlerock Creek ID	2.3
Mojave WA	75.8
Palmdale WD	17.3
Total	239.6

Source: DWR (1998, p9-17)

Figure I-16. CALVIN's Representation of Owens Valley



COLORADO RIVER HYDROLOGIC REGION

Introduction

The Colorado River Region covers 19,730 square miles in the southeast corner of the state. It includes all of Imperial County and parts of Riverside, San Bernardino and San Diego Counties. The Sate of Nevada, the Colorado River, and the Mexican border form the eastern and southern boundaries. The Mexican border lies to the south. From the Nevada state line, the northern boundary follows the crest of the New York Mountains and the drainage divide between the Mojave River to the north, and Twenty-Nine Palms area to the south. The western boundary is formed by a series of mountain ranges: the San Bernardino; the San Jacunte, the Santa Rosa; the Volcan; and the Laguna Mountains. For planning purposes, DWR divides the region into six PSAs:

- Borrego;
- Chuckwalla;
- Coachella;
- Colorado River;
- Imperial Valley; and
- Twenty-Nine Palms-Lanfair.

The Colorado River PSA is a 20 to 30 mile wide area on the west bank of the Colorado River that drains into the river. Coachella Valley and Imperial Valley are located in the Salton Trough to the north and south of the Salton Sea. The remaining PSAs are predominantly mountainous.

Climate

Imperial County has a typical desert climate characterized by low precipitation, hot, dry summers and mild winter temperatures. Reference crop evapotranspiration is much greater than for the Central Valley, averaging approximately 88 inches/year in the agricultural areas. Annual precipitation is low, averaging 5.5 inches (DWR 1994, Vol. 2, p245).

Land Use

There are three main centers of agricultural activity within the region: Imperial Valley; Coachella Valley; and Palo Verde Valley. In addition a small area of irrigation is located in the Bard Valley, in the southeastern corner of the county adjacent to the Colorado River. The major water agencies are the Imperial Irrigation District (IID), the Palo Verde Irrigation District (PVID) and the Bard Valley Water District[3] (BVWD). Outside their service areas, the region is mostly arid and undeveloped. The population is mostly located in the Coachella and Imperial Valleys.

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[3] In some reports referred to as Bard Valley Irrigation District

Table I-25. Colorado River HR, Cropped Acreage

PSA	1995			2020		
	Land (ac)	Crops (ac)	Crops (%)	Land (ac)	Crops (ac)	Crops (%)
29 Palms-Lanfair	4,070	4,070	0.5	7,180	7,180	1.0
Chuckwalla	4,900	4,900	0.7	3,700	3,700	0.5
Colorado	105,050	129,750	17.4	103,100	133,760	17.8
Coachella	59,110	73,420	9.8	34,400	38,300	5.1
Borrego	8,330	9,730	1.3	10,980	13,580	1.8
Imperial	462,580	525,780	70.3	445,600	553,100	73.8
Total	**644,040**	**747,650**	**100**	**604,960**	**749,620**	**100**

Source: DWR Bulletin 160-98 supporting data

Imperial Irrigation District

The fertile soils of Imperial Valley make Imperial the 10th (in 1994) most important agricultural county in the state. Agriculture within the valley is entirely within the Imperial Irrigation District (IID) service area. IID is by far the largest agricultural center in the county with an irrigated acreage of approximately 460,000 acres.

Palo Verde Irrigation District (PVID)

The PVID serves agriculture in the Palo Verde Valley. The majority of the agriculture is in Riverside County, but approximately 7,600 acres are located in Imperial. PVID diverts water from the Colorado River into the Palo Verde Canal near the town of Blythe.

Bard Valley Water District (BVWD)

Bard Valley forms the northwestern part of Yuma Valley, a 170 square mile basin that drains to the Colorado River. Irrigated agriculture covers about 14,700 acres supplied from both surface and groundwater. BVWD operates the diversion facilities of the Reservation Unit of the USBR Yuma Project. Diversions to the unit are made from the All-American Canal, 18 miles downstream of the headworks at Imperial Dam. Groundwater is pumped from an unconfined aquifer. Current extraction is about 170 ac-ft/yr. Pumping has reversed the historic hydraulic gradient, and the aquifer is now recharged from the Colorado River and by seepage from the All-American Canal.

Coachella Valley Irrigation District (CVID)

The majority of CVID lies within Riverside County, to the north of the Salton Sea. The southern part of the district extends into Imperial and San Diego Counties. CVID receives surface water supplies from the Colorado River via the All-American Canal. The irrigated acreage is projected to drastically reduce by the year 2020 due to urbanization.

Water Supplies

Table I-26 below gives DWR estimated water supplies for the year 2020.

Table I-26. Colorado River HR Water Supplies (taf)

Supplies	2020 average	2020 drought
Surface Water	3,920	3,909
Groundwater	285	284
Total	4,205	4,193

Source: DWR 1998, p9-28

Rim Flows

(a) New River

The New River originally was supplied by overflow from the Colorado River. Since development of storage on the Colorado River, the river now originates in Mexico near the city of Mexicali. The river receives considerable agricultural runoff and municipal and industrial wastewater within Mexico. Figures for flows at the international border vary, but are in the order of 150,000 - 250,000 af/yr. The river is heavily polluted and is unusable as a source of water for municipal supply or irrigation. However, two industries hold a 75,000 af (97 cfs) water right to flows in the river. Within the Imperial Valley, the New River receives additional water from canal operational spills, tailwater, and tile drain discharge. The 1987-1996 average annual outflow to the Salton Sea was 597,000 af.

(b) Alamo River

The Alamo River, though smaller, is similar to the New River. It originates in Mexico and flows through IID to discharge into the Salton Sea. Within Mexico, the river receives water primarily from agricultural drainage in eastern Mexicali Valley. Within Imperial Valley, the river receives drainage water from IID. The 1987-1996 average annual flow rate rises from 2,000 af (3 cfs) at the international border to 446 af (816 cfs) at the point of discharge to the Salton Sea.

(c) White River

Originally the White River flowed through the Coachella Valley to discharge into the Salton Sea. River flows are now used to recharge the groundwater via percolating ponds operated by the Coachella Valley Water District. Although the White River is represented by CALVIN, inflows are currently set to zero.

Local Water Supplies

Salton Sea

The Salton Sea is the sink of a closed basin. Agricultural drainage water from Imperial and Coachella Irrigation Districts are the main source of inflow. Current salinity levels of 41,000 mg/l make the Salton Sea unusable as a source of agricultural or urban water.

Imports

The Colorado River is the only significant source of usable surface water in the Colorado River Region. The combination of low precipitation, high evaporation, and coarse soils outside the Imperial Basin results in infrequent and low runoff. Surface water originating from Mexico is of low quality with high total dissolved solids (TDS). The Colorado River is subdivided into the upper and lower basin. California, Arizona and Nevada make up the Lower Basin states. Under the Boulder Canyon Project Act (1928), Congress divided the 7.5 million acre-feet apportioned to the Lower Basin states, allocating 4.4 maf/yr to California, 2.8 maf/yr to Arizona, and 0.3 maf/yr to Nevada. The 1929 California Limitation Act limits California's use to 4.4 maf plus not more than one-half of any excess or surplus unapportioned water. Major diversions from the Colorado River are made into the All-American Canal and into the Colorado River Aqueduct. Local diversion is made near Blythe for PVID.

Colorado River Aqueduct

The Colorado River Aqueduct, owned by MWDSC, is used to transfer their apportionment to the south coast. It also serves two SWP contractors, Desert Water Agency and Coachella Valley Water District, through an exchange agreement with MWDSC.

All-American Canal

IID operates Imperial Dam, which acts as a diversion structure for the All-American Canal. The unlined canal is 82 miles long and supplies water to the California Division of the Yuma Project, CVWD and IID. The Yuma Project diverts 2,000 cfs from turnouts upstream of the Siphon Drop Power Plant. The Coachella Canal diverts water at Drop No 1. Downstream of Drop No 1., the canal delivers water to the IID via three branches: the East Highline, Central Main, and Westside Main Canals.

Flow in the All-American Canal is measured at a gauging station near Pilot Knob, immediately downstream of releases back to the Colorado River. 1989-1996 average flows are 3,258,000 af at Pilot Knob, of which 324,000 af is diverted into the Coachella Canal. Evaporation and seepage losses during this period upstream of the East Highline Canal are estimated at 99,000 af/yr. USBR estimates that 70,000 af are lost through seepage along a 23-mile section downstream of Pilot Knob. Lining this section would save 67,700 af annually.

Coachella Canal

Colorado River water is supplied to CVID via the Coachella branch of the All-American Canal. The Coachella Canal branches from the All-American Canal 37 miles downstream of Imperial Dam. It stretches 122 miles before terminating in the Lake Cahuilla re-regulating reservoir. The capacity is 1300 cfs (equivalent to 941,200 af/yr).

The canal is concrete-lined, except for a section of 38 miles adjacent to the Salton Sea. DWR (1994, Vol. 2, p261) estimates current canal seepage to be 32,400 af/yr. It is estimated that lining this remaining section would save 25,700 af/yr.

Morongo Basin Pipeline

The Morongo Basin Pipeline delivers SWP water for groundwater recharge in to Desert Water Agency service area.

Exports

The Colorado River Aqueduct is owned and operated by MWDSC. The majority of flow in the aqueduct is exported to the South Coast Region. However MWDSC has an exchange agreement with the Desert Water Agency and the Coachella Valley Water District that allows MWDSC to use the two agencies SWP entitlement water. In return, water is diverted from the aqueduct to recharge groundwater in the Coachella Valley.

Water Rights and Contractual Agreements

Apportionment of the Colorado River between local agencies was established by the Seven Party Agreement in 1931. Within Imperial County, this includes PVID, BVD, IID, and CVWD. Additional signatories to the agreement were MWDSC, the City of Los Angeles, the City of San Diego, and the County of San Diego. Table I-27 gives the relative priorities.

Table I-27. Intrastate Seven Party Agreement

Priority	Description
1	Palo Verde Irrigation District, based on area of 104,500 acres
2	California land in USBR's Yuma Project, not to exceed 25,000 acres
3	Land irrigated from the All-American Canal in Imperial and Coachella Valley and Palo Verde
	Priorities 1-3 not to exceed 3.85 maf/yr
4	MWDSC for coastal plain of Southern California, up to 550,000 af/yr
5	MWDSC additional 550,000 af/yr and City & Co of San Diego 112,000 af/yr
6	Land irrigated from the All-American Canal in Imperial and Coachella Valley and Palo Verde
	Priorities 1-6 not to exceed 5.362 maf/yr
Notes	Indian tribes and misc. present perfected right holders have right to divert additional San Diego has transferred its apportionment to MWDSC

Source: DWR, Bulletin 160-98

Under the first priority, Palo Verde Irrigation District was given an entitlement of enough water to irrigate 104,500 acres. Under the second priority, the Reservation Division of the Yuma Project was given enough water to irrigate 25,000 acres. Under the third priority, the lands in the Imperial and Coachella Valleys, along with 16,000 acres of land on the Lower Mesa in Palo Verde Valley, were given the entire 3.85 million acre feet entitlement, less whatever had been used by the first two priorities. Under the fourth priority, Metropolitan Water District was assigned 550,000 acre-feet which used up the balance of California's 4.4 million acre-feet. On the assumption that there would be additional water available (either from surplus or from unused entitlements belonging to the other two lower basin states), a fifth priority assigned an additional 550,000 acre-feet to MWD and 112,500 acre-feet to the City and County of San Diego. The City and County of San Diego later assigned that entitlement to MWD when the San Diego County Water Authority joined MWD. Remaining waters available thereafter were assigned again to the agricultural agencies by the sixth and seventh priorities.

Under the Seven Party Agreement, the three local water agencies serving agricultural land and USBR's Yuma Project Reservation Division hold the first three priorities totaling 3.85 maf/yr. However, none of the agencies are assigned a specific quantity of water, but instead hold an entitlement to irrigate certain land. Disputes between IID and CVWD over the third priority were settled by an Agreement of Compromise (1934) that established a priority of IID over CVWD. In 1979, the US Supreme Court in *Arizona v. California* quantified mainstream present perfected rights[4] in the Lower Basin states. The ruling determined that IID has a present

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[4] Present perfected water rights are defined as rights acquired in accordance with state law and exercised by diversion and use on a defined area as of June 1929.

perfected right to 2.6 maf or the quantity of water needed to irrigate 424,145 acres. In times of shortage, present perfected rights must be satisfied first.

Four SWP contractors are located within the Hydrologic Region: Desert Water Agency; Coachella Valley Water District; Mojave Water Agency; and San Gorgonio Pass Water Agency. Currently, facilities (Morongo Pipeline) exist to supply only MWA from the California Aqueduct. SGPWA will receive SWP water after the extension of the East Branch of the California Aqueduct scheduled for completion by 2020. DWR and CVWD have entered into an agreement with MWDSC to receive Colorado water. Water is released from the Colorado River into the Whitewater River for artificial recharge of the upper Coachella groundwater basin. MWDSC takes an equal amount of the agencies' SWP water from the California Aqueduct. The SWP entitlements are given below. The total entitlement allocated to the Colorado River region is 85.8 taf.

Table I-28. Colorado River HR, SWP Contractors

	Total Annual Entitlement (taf)
Coachella Valley Water District	23.1
Desert Water Agency	38.1
Mojave Water Agency	75.8
San Gorgonio Pass Water Agency	17.3
Note: Of the 75.8taf DWA entitlement, 7.3 is allocated to the Colorado River region	

Table I-29. Colorado River HR, Summary of Surface Water Entitlements

Agency	Annual Entitlement (taf)
Intrastate Seven Party Agreement, priorities 1-3	3,850.0
Less transfer from IID to MWDSC under conservation program	-106.0
Less transfer from IID to MWDSC under All-American Canal lining	-68.0
SWP water	85.8
Total	3,761.8

References:

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