APPENDIX H

INFRASTRUCTURE

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INTRODUCTION

Modeling California's surface water storage and conveyance facilities requires vast amounts of data, even with CALVIN's aggregated approach. This appendix outlines CALVIN's representation of California surface water reservoirs, specific assumptions necessary in representing certain reservoirs, and CALVIN's representation of conveyance facilities. In addition, data source documentation, a key component of the CALVIN project, is provided.

RESERVOIR MODELING METHODOLOGY

CALVIN uses capacity, surface area, evaporation, and simple elevation-area-capacity relationships to model reservoir operations in determining its optimal solution. This section describes criteria used to determine which reservoirs are included in CALVIN, calculation of maximum and minimum storage levels, derivation of elevation-area-capacity relationships, and evaporation methodology.

Criteria for inclusion in CALVIN

Generally, surface water reservoirs are represented in the schematic if they have a maximum total storage of 50 taf or larger. Aggregated reservoirs were developed for smaller reservoirs operating in close proximity or if there were other important factors (e.g., water quality). All aggregated reservoirs assume simultaneous fill and draw down rates. For every reservoir, it was necessary to determine a minimum and a maximum storage, an elevation-area-capacity relationship, and an area-capacity factor.

Maximum and Minimum Storage Levels

The maximum storage data generally represent either the top of the conservation pool (the total storage minus that reserved for flood control), or the physical capacity of the reservoir if it is not used for flood control. Maximum storages for aggregated reservoirs are simply the total of the physical capacities of the individual reservoirs. Dry lake beds in the Tulare Basin have no maximum storage level, since they are modeled as sinks in CALVIN.

Most minimum storage values reflect the estimated dead pools. East Bay MUD aggregate, Los Vaqueros, Eastside reservoirs, along with Lake Mathews and Lake Skinner, use the emergency pools as the minimum storage levels. Where minimum storage data was deficient, dead pool was estimated to be 10% of maximum storage.

The Thermalito Afterbay is the only reservoir currently modeled with minimum and maximum storage levels based on hydropower storage limitations.

Initial and Final Storage Calculations

For reservoirs where DWRSIM, SANJASM, PROSIM, or HEC-3 data were developed (discussed in the next section), the initial storages from these models' input data are used in CALVIN. In addition, USBR and MWD data from other studies were helpful in determining initial storage conditions for Lake Skinner and Salton Sea. For reservoirs included in CALVIN and not in these studies, initial storage was assumed to be 50% of the maximum usable storage (maximum storage minus dead pool storage). The 50% value represents a weighted average of reservoir levels in DWRSIM run 514a. For the Unconstrained Case, the ending reservoir storages were set to equal the ending Base Case storages, ensuring that the overall amount of surface water in each run remains the same.

Further information regarding initial storage calculations can be found in “Initial Storage Calcs edMF.xls” in the Software and Data Appendices folder under Appendix H, in the supporting computer files.

Elevation-Area-Capacity Relationships

The elevation-area-capacity data are paired data sets relating the water surface area and elevation to different reservoir storage levels. Eight to ten data points for area, capacity, and elevation defined the area-capacity-elevation relationship when data were available. Otherwise, the area-capacity relationship was assumed to be linear between the maximum storage and surface area and the origin, producing a triangular cross-section. Elevation data was also included for these points if it was available, but set equal to zero if not. All aggregated reservoirs use this assumption. These data are not used directly in the model solution, although they can be used for post-processing reservoir elevations.

Evaporation Methodology

Monthly evaporation losses in CALVIN are calculated by multiplying a monthly evaporation rate by the corresponding surface area for any month.

Area-Capacity Factor: For CALVIN reservoirs, the area capacity factor is calculated as the slope of the line between the minimum and maximum capacity and surface area points in the elevation-area-capacity relationship. This factor was taken directly from DWRSIM, PROSIM, or SANJASM input files when possible, or derived individually for reservoirs not represented in DWRSIM.

Monthly Evaporation Figures: For the majority of reservoirs, average monthly evaporation figures were generated for each month and then applied over the period of record. DWRSIM supplied the majority of information, although a few Northern California reservoirs and several Southern California reservoirs required different assumptions.

Annual figures were obtained for Lake Skinner, Lake Mathews, and Eastside Reservoir from Upadhyay (1998). To convert these annual values into monthly values, DWRSIM estimates for Lake Perris were scaled to find the estimated monthly evaporation. Explicitly,

$$\text{Monthly Evaporation} = \frac{\text{Monthly Evap for Lake Perris}}{\text{Annual Evap for Lake Perris (3.85 ft)}}\text{(Annual Evap for reservoir)}$$

RESERVOIR REPRESENTATION

A wide variety of assumptions were needed to complete the representation of reservoirs included in CALVIN. Many of these assumptions have to do with the HEC-PRM model being based on monthly time steps, while many of the actual constraints are daily or annual, or dependent on some other aspect beyond the capability of this model. For example, many of the flood control constraints depend on rainfall and antecedent moisture conditions not explicitly modeled in CALVIN. This section outlines the approach adopted for specific reservoirs in each of the five sub-regions in CALVIN. Supporting documentation and calculations can be found in the Software and Data Appendices folder, under Appendix H.

Table H-1 on the following page contains the parameters for each of the reservoirs included in the CALVIN model, where reservoirs are grouped by sub-region. Values for minimum and maximum capacities for the reservoirs are listed, as well as the capacity limitation type. The Area-Capacity Factor is used to calculate evaporative losses. Finally, the initial storage values are included, since much of the subsequent reservoir operations are dependent on the amount of storage initially available in the system.

Table H-1. Surface Reservoir Data and Sources

Region	Reservoir	CALVIN name	Minimum Capacity (taf)		Maximum Capacity (taf)		Area-Capacity Factor	Initial Storage (taf)
			Data	Type	Data	Type		
1	Clair Engle Lake	SR-1	400	dead pool	MV	flood	0.006135	2053
1	Whiskeytown Lake	SR-3	10	dead pool	MV	flood	0.012485	200
1	Shasta Lake	SR-4	116	dead pool	MV	flood	0.00647	2496
1	Black Butte Lake	SR-BBL	10	dead pool	MV	flood	0.018526	80.2
2	Lake Oroville	SR-6	29.6	dead pool	UBC	flood	0.004065	2555
2	Thermalito Afterbay	SR-7	15.2	hydro min	54.9	hydro max	0.07	49.4
2	Folsom Lake	SR-8	83	dead pool	UBC	flood	0.01117	549
2	Camp Far West Reservoir	SR-CFW	1	dead pool	103	max	0.002602	35
2	Clear Lake & Indian Valley Reservoir	SR-CL-IVR	0	undocumented	MV	flood	0.032558	306.7
2	Camanche Res	SR-CR	4	unknown	UBC	flood	0.005604	200
2	EBMUD aggregate	SR-EBMUD	83	emerg. pool	MV	flood	0.010739	117.9
2	Englebright Lake	SR-EL	50	dead pool	MV	flood	0.010196	66
2	Lake Berryessa	SR-LB	10.3	undocumented	1602.3	max	0.009746	806.3
2	Los Vaqueros Reservoir	SR-LV	72	emerg. pool	104.8	max	0.010139	88.3
2	New Bullards Bar Res	SR-NBB	251	dead pool	MV	flood	0.005066	600
2	New Hogan Lake	SR-NHL	17.5	unknown	UBC	flood	0.011182	159
2	Pardee Reservoir	SR-PR	12.2	unknown	MV	flood	0.007292	195
3	New Melones Reservoir	SR-10	80	dead pool	MV	flood	0.004627	1000
3	San Luis Reservoir	SR-12	80	dead pool	2038	max	0.00997	525
3	Lake Del Valle	SR-15	9.8	dead pool	40	max	0.012203	28
3	Millerton Lake	SR-18	120	dead pool	MV	flood	0.008752	176
3	Lake McClure	SR-20	115	dead pool	UBC	flood	0.00638	229
3	Los Banos Grandes Reservoir	SR-22	Proposed Storage: no values			none		
3	Hensley Lake	SR-52	4	dead pool	UBC	flood	0.013405	24
3	Eastman Lake	SR-53	10	dead pool	UBC	flood	0.008745	58
3	New Don Pedro Reservoir	SR-81	100	dead pool	UBC	flood	0.005772	373
3	SF aggregate	SR-ASF	31	dead pool	225	max	0.019124	128
3	Hetch Hetchy Reservoir	SR-HHR	36	estimated	360	max	0.005433	330.6
3	Lake Lloyd/Lake Eleanor	SR-LL-LE	30.1	estimated	301.3	max	0.008241	216.6
3	Santa Clara Aggregate	SR-SCV	37	estimated	170	max	0.02047	94
4	Buena Vista Lake Bed	SR-BVLB	Dry lake bed: no values			none		
4	Lake Isabella	SR-LI	0.184	none	MV	flood	0.011412	281.9
4	Lake Kaweah	SR-LK	0.57	none	MV	flood	0.005912	77.1
4	Lake Success	SR-LS	0.557	none	MV	flood	0.02237	41.9
4	Pine Flat Reservoir	SR-PF	45.379	estimated	MV	flood	0.003778	550
4	Tulare Lake Bed	SR-TLB	Dry lake bed: no values			none		
4	Turlock Reservoir	SR-TR	11	unknown	67	max	0.019225	65
5	Silverwood Lake	SR-25	44	dead pool	73	max	0.00558	50
5	Lake Perris	SR-27	31	dead pool	127	max	0.0183	108
5	Pyramid Lake	SR-28	95	dead pool	170	max	0.00725	170
5	Castaic Lake	SR-29	294	dead pool	324	max	0.00798	294
5	First priority Colorado River 4.4 water	SR-CR1	0	none	none	max	0	0
5	Second priority Colorado River 4.4 water	SR-CR2	0	none	none	max	0	0
5	Colorado River Storage for MWD (850 taf/yr)	SR-CR3	0	none	4400	max	0	0
5	Eastside Reservoir	SR-ER	400	emerg. pool	800	max	0.00508	600
5	Grant Lake	SR-GL	4.75	estimated	47.525	max	0.022461	26
5	LAA Storage	SR-LA	10.2	estimated	102.5	max	0.03165	52
5	Long Valley Reservoir (Lake Crowley)	SR-LC	18.3	estimated	183.5	max	0.0243	92.5
5	Lake Mathews of MWDSC	SR-LM	78.5	emerg. pool	182	max	0.0175	100.1
5	Lake Skinner	SR-LSK	33.8	emerg. pool	44.2	max	0.0279	33.8
5	Mono Lake	SR-ML	MV	env constraint	none	max	0.014	2940
5	Owens Lake	SR-OL	Dry lake bed: no values			none		
5	Salton Sea	SR-SS	0	none	none	max	0.017	6941

Data Sources

Table H-2 outlines the general sources of information used in gathering this data. Detailed source listings for each reservoir will be listed in the next section of this report.

Table H-2. Information Sources For Surface Water Reservoirs

Reservoirs	Source
SWP and CVP reservoirs	DWR (1998b)
Tuolumne River facilities	USBR (1997), DWR (1993)
USACE facilities	Johonnot (1998)
EBMUD facilities	Garland (1998)
MWD facilities	Upadhyay (1997)
Clear Lake and Indian Valley Reservoirs	Barton (1998)
Owens Valley surface storage	DWR (1993)

Department of Water Resources

Most of the State Water Project and Central Valley Project reservoirs included in CALVIN utilize capacity and evaporation parameters specified in DWRSIM Run 514 input files (DWR 1998b). These reservoirs use numeric labels in CALVIN (e.g. SR-15). Additionally, DWR's Bulletin 17-93 reservoir capacities were used to characterize several Southern California facilities, including Grant Lake, LAA Storage, Long Valley Reservoir, and Lake Mathews.

US Bureau of Reclamation

Four reservoirs in the Central Valley Project system are not included in the DWRSIM model: Camanche, Pardee, and Turlock Reservoirs, and New Hogan Lake. Capacity and evaporation parameters for these facilities were taken from the CVPIA-PEIS studies which utilize the SANJASM and PROSIM models (USBR 1997).

US Army Corps of Engineers

The Black Butte Lake Master Plan, published by the USACE, provided representation data for Black Butte Lake in Northern California. Also, since the Tulare Basin is largely not included in the statewide planning models (DWRSIM, PROSIM, and SANJASM), reservoir parameters for the Tulare Basin reservoirs were obtained from USACE personnel (Johonnot 1998).

Metropolitan Water District

The "Southern California Integrated Water Resources Plan", published by MWD provided data on Lake Skinner. Data on Eastside Reservoir and Lake Mathews were obtained through personal contact with MWD personnel (Upadhyay 1998).

Other

Since many of the reservoirs included in CALVIN are not included in current statewide planning models with easily accessible data, a number of other studies were used in defining individual reservoir representations. These individual sources are listed in the following section, along with detailed explanations of how these reservoirs are modeled. Reservoirs that utilize a number of different sources are also included.

Specific Reservoir Representations

This section describes reservoirs whose representation or data sources are not adequately described in the previous section.

Clair Engle Lake (Region 1)

Though capacity and initial storage values are obtained from DWRSIM for Clair Engle Lake, evaporation rates from the CVPIA-PEIS PROSIM run are used. Reasoning behind this decision is undocumented.

Black Butte Reservoir: SR-BBL (Region 1)

The minimum storage for Black Butte is considered dead pool, derived from the Black Butte Master Plan (USACE 1977). The maximum storage time series was computed as an average of the top of the conservation pool measurements for the 1964 to 1998 time period (Johonnet 1998). The actual operating procedures for these rules are assumed to depend on antecedent moisture conditions and other factors not included in the HEC-PRM input. It may be worth noting that the averages for the summer months did not reach full capacity (160 taf), which commonly occurs in practice. The average for these months was closer to 150 taf. Thus, the simulated operation of Black Butte may underestimate its summer contribution to storage by approximately 10 taf.

Clear Lake and Indian Valley Reservoir Aggregation: SR-CL-IV (Region 2)

Liberal estimates were used for flood reservation pools for both Indian Valley and Clear Lake, thus slightly reducing annual supply potential. This was done because both sets of operating rules fluctuated within months, which is beyond the capability of CALVIN and HEC-PRM. For example, for April 1 there is up to 581.39 taf of water supply storage possible; on April 15, this amount increases to 589.39 taf. In the Calvin representation, as a result of the monthly time-steps, the maximum water supply pool was estimated to be 589.39 taf for the entire month of April.

No water supply can be diverted from the immense amount of dead storage within Clear Lake (over 840 taf). In practice, only local water users have access to this water (Barton 1998).

For Indian Valley, evaporation and surface area were interpolated to correspond to Clear Lake values. The maximum and minimum values were assumed to occur at a lake elevation of 59 ft and 0 ft, respectively. Intermediate values were interpolated. Although this provides a crude estimation of Indian Valley values, it is justified in this aggregation since its values are so small relative to Clear Lake's (only 9% of the surface area and 7% of the evaporation by volume occur in Indian Valley).

Annual evaporation for Clear Lake and Indian Valley Reservoir is estimated to be 4.5 ft and 3.33 ft, respectively (Barton 1998; DWR 1975). Annual evaporation for the aggregated reservoir is 4.4 ft/yr. This value was derived by dividing the annual evaporation (in acre-feet) by area (in acres) at every possible level for the aggregated reservoir. This implicitly assumes that the Clear Lake and Indian Valley are filled and emptied simultaneously.

EBMUD Aggregated Reservoir: SR-EBMUD (Region 2)

A significant amount of surface water storage exists within the EBMUD service area for water supply purposes. Thus, the local EBMUD reservoirs have been aggregated into one water supply reservoir for the CALVIN model (See Table H-3).

Table H-3. EBMUD Reservoirs

Reservoir	Capacity (taf)
Briones	60
Chabot	10
Lafayette	4
San Pablo	38
Upper San Leandro	41
Total	**153**

For representation of elevation-area-capacity relationships, each reservoir is assumed to fill and release at the same time. Elevation outputs from CALVIN represent the total height of the aggregated reservoir. The maximum and minimum monthly storage values are also added together and included as constraints. EBMUD maintains a significant volume of emergency storage (83 to 103 taf depending on the month), as reflected in these constraints. Local inflows to each reservoir are neglected.

Aggregated reservoir evaporation values correspond to a weighted average of annual evaporation/rainfall for each reservoir. The evaporation/rainfall values were calculated by dividing the monthly loss or gain (in acre-feet) by the corresponding approximate surface storage area. Since the surface storage area is not readily available for a consistent time span, each reservoir uses a different time period for the evaporation calculations—this time period represents the longest period of continual data for the reservoir.

It should be noted that the annual evaporation using these estimates is unusually low (0.84 ft/yr). To include evaporation for the 1921-1993 period of record used in CALVIN, the above weighted average will be assumed to be annual.

SR-EBMUD parameters were obtained from EBMUD personnel (Garland 1998). The EBMUD web page may also provide additional background information (EBMUD 1999).

Los Vaqueros Reservoir: SR-LV (Region 2)

The Contra Costa Water District uses Los Vaqueros for emergency purposes in addition to water supply. Thus, minimum storage is equal to the dead storage plus 70 taf of emergency storage. Capacity and evaporation parameters were provided through CCWD personnel. Further information is available on the CCWD web site (CCWD 1999).

Thermalito Afterbay (Region 2)

For Thermalito Afterbay, the maximum and minimum storages represent the operating limitations for hydropower (Miller 1999). The evaporation rate is given in DWRSIM for Thermalito Forebay.

Camp Far West Reservoir (Region 2)

Input files for an HEC-3 watershed model of the Bear River by the Department of Water Resources provided parameters for this reservoir (DWR 2000a).

Englebright Lake: SR-EL and New Bullards Bar Reservoir: SR-NBB (Region 2)

Input files for an HEC-3 watershed model of the Yuba River by the Department of Water Resources provided parameters for these two reservoirs (DWR 2000b).

Lake Berryessa (Region 2)

Reservoir parameters were obtained from the Solano County Water Agency (Roland 1999).

Hetch Hetchy Reservoir: SR-HHR (Region 3)

The maximum storage and surface area for Hetch Hetchy was found in Bulletin 17-93. The elevation-area-capacity relationship for the SR-HHR assumes a triangular cross section. Because no data could be found for dead storage, the dead storage was arbitrarily assumed to equal 36 taf, or ten percent of maximum storage. The monthly evaporation rate was assumed to equal that of New Don Pedro Reservoir.

Lake Lloyd/Lake Eleanor: SR-LL-LE (Region 3)

Maximum storage for Lake Lloyd (279 taf) and Lake Eleanor (28 taf) was found in DWR (1993). Because these reservoirs are not used for flood control, the maximum storage was assumed to equal the sum of these two values. Because no data could be found for dead storage, the dead storage was arbitrarily assumed to equal 30.1 taf, or ten percent of the maximum storage. The monthly evaporation rate was assumed to equal that of New Don Pedro Reservoir.

San Francisco Public Utilities Commission (SFPUC) Reservoirs: SR-ASF (Region 3)

For water supply purposes, CALVIN aggregates several SFPUC reservoirs (See Table H-4).

Table H-4. SFPUC Reservoirs

Reservoir	Capacity (taf)
San Andreas	19
Crystal Springs	58
San Antonio	51
Calaveras	97
Total	**225**

Bauer (1998) provided elevation-area-capacity data for each reservoir. Because these reservoirs are not used for flood control, the maximum storage of the aggregate reservoir is simply the sum of the maximum capacities for each reservoir. The dead storage equals the sum of the dead storages for each reservoir. Elevation-area-capacity relationships for the SR-ASF assume a triangular cross section. Monthly evaporation data were taken from the CCWD's Los Vaqueros Reservoir (SR-LV).

Capacity and evaporation calculations can be found in "SFPUC Reservoirs.xls" in the Software and Data Appendices under Appendix H in the supporting computer files.

Santa Clara Aggregate: SR-SCV (Region 3)

Major reservoirs have been aggregated according to SCVWD (1997) (See Table H-5).

Table H-5. Santa Clara Valley Reservoirs

Reservoir	Capacity (taf)
Anderson	89
Calero	10
Chesbro	9
Coyote	23
Guadalupe	3
Lexington	20
Pacheco	6
Uvas	10
Total	**170**

The aggregate maximum storage is the sum of the storage values. Because no data could be found for dead storage, the dead storage was arbitrarily assumed to equal 17 taf, or ten percent of the maximum storage. Elevation-area-capacity relationships for the SR-SCV assume a triangular cross section. Monthly evaporation data were taken from the CCWD's Los Vaqueros Reservoir (SR-LV).

Tulare Basin Reservoirs: SR-PF, SR-LK, SR-LI, and SR-LS (Region 4)

Four Tulare Basin reservoirs are included in CALVIN: Pine Flat, Lake Kaweah (Terminus Dam), Lake Success, and Lake Isabella. Since these facilities are not currently included in statewide planning models, USACE data were used to calculate evaporation and maximum flood control levels.

For evaporation and water supply limits, the following time series were provided by the Sacramento District of the US Army Corps of Engineers (Johonnot 1998):

Table H-3. Tulare Basin Reservoir Parameter Sources

Reservoir	Period of Record
Pine Flat Lake	1954-1998
Lake Success	1961-1998
Lake Kaweah	1962-1998
Lake Isabella	1953-1998

Daily average evaporation was provided in inches/day and was converted to monthly values by averaging over the entire period of record. These values were then converted to feet/month and repeated over the entire CALVIN time period (October 1921-September 1993).

Monthly storage limits were computed similarly-- daily values were converted into monthly values and averaged over the entire period of record. Inter-annual variation in flood control space is ignored. The values collected from the USACE were in terms of 'midnight bottom of transition space in Ac-Ft'. A limitation of this method may be that the averages over the entire period of record may not reflect stricter flood control regulations enforced later.

Colorado River Reservoir Representation: SR-CR (Region 5)

In accordance with legal restrictions on California's diversion of Colorado River water, a reservoir has been developed to mimic current legal restrictions-- an exception to the physical representation sought by the CALVIN schematic. The reservoir has an inflow of 4.4 million acre-feet every October with no evaporation and a 4.4 million acre-foot capacity. SR-CR is constrained to empty at the end of every September, thus not creating any artificial additional storage to be used in subsequent years.

East Side Reservoir: SR-ER (Region 5)

The East Side reservoir project, shown on the schematic, is scheduled for completion in 2004. 400 taf of SR-ER is reserved for emergency storage and not available for standard operational water supply.

Grant Lake (Region 5)

Maximum capacity for Grant Lake was taken from DWR (1993), and minimum capacity was assumed to be 10% of maximum storage. Evaporation rates were assumed to be equal to Lake Isabella rates (Johonnet 1998).

Lake Skinner: SR-LSK (Region 5)

Although Lake Skinner has a capacity of only 44 taf, it is included in CALVIN for water quality purposes. Parameters were all derived from MWD (1996).

Los Angeles Aqueduct Reservoirs: SR-LA (Region 5)

Several reservoirs in the LAA system have been aggregated into one just south of Owens Lake in Inyo County, California (See Table H-4).

Table H-4. LAA Reservoirs

Reservoir	Capacity (taf)
Pleasant Valley	3
Tinemaha	16
Haiwee	39
Fairmont	0.5
Bouquet	34
Los Angeles	10
Total	**102.5**

Like Grant Lake, maximum capacity was taken from DWR (1993), and minimum capacity was assumed to be 10% of maximum storage. Evaporation rates were assumed to be equal to Lake Isabella rates (Johonnet 1998).

Long Valley Reservoir (Region 5)

Maximum capacity was taken from DWR (1993), and minimum capacity was assumed to be 10% of maximum storage. Evaporation rates were assumed to be equal to Lake Isabella rates (Johonnet 1998).

Lake Mathews (Region 5)

Evaporation parameters were derived from Upadhyay (1998). Minimum capacity was taken from MWD (1996). Maximum capacity and initial storage was calculated from DWR (1993).

Mono Lake: SR-ML and Salton Sea: SR-SS (Region 5)

For a description of CALVIN's representation of these lakes, see *Appendix F: Environmental Constraints.*

CONVEYANCE

This section discusses the modeling methodology, capacity determination, data sources, and special considerations of California's conveyance facilities represented in CALVIN. Supporting files in "Software and Data Appendices/Appendix H" elaborate on the general information presented in this section, and should be referenced for more detailed analysis.

In many cases, the conveyance facilities in CALVIN represent the aggregation of many smaller facilities or diversions. For example, the left and right bank diversions to the CVPM 2 agricultural region from the Sacramento River have been aggregated into a single link. These simplifications, while maintaining reasonable accuracy, significantly reduce the complexity of the model and prevent unnecessary computational burdens.

Canals and Pipelines

As with reservoir data, much of CALVIN's information regarding conveyance facilities uses DWRSIM and CVPEIS information (DWR 1998b; USBR 1997). Since CALVIN extends into geographical regions beyond the scope of DWRSIM, SANJASM, and PROSIM, several other modeling efforts contributed as well. In the Tulare Basin and the southern San Joaquin Valley, DWR (1989) provided a reasonably detailed schematic of the Friant-Kern Canal and the Kern County Water Agency delivery system. Southern California canal and pipeline capacities were mostly collected from modeling efforts of MWD and SDCWA (MWD 1997; SDCWA 1998). IID (1998) contributed to CALVIN's representation of the All American Canal. Table H-5 summarizes the additional data sources that provided the constraints and layout for CALVIN's entire network.

Table H-5. Information Sources For Canals and Pipelines

Facilities	Source
DWR facilities	
California Aqueduct and SWP	DWR (1997)
Pacheco Tunnel	DWR (1987)
USBR facilities	
General CVP facilities	DWR (1987)
Putah South Canal (Solano ID)	Rubin (1988)
Kern County	DWR (1989)
Friant-Kern Canal	FWUA (1998)
Local facilities	
SFPUC—Tuolumne River facilities	USBR (1987)
Contra Costa Water District service area	CCWD (1999)
Mokelumne River and EBMUD service area	EBMUD (1999)
MWD service area	MWD (1997)
SDCWA service area	SDCWA (1997)
Coachella Canal	CVWD (1999)
IID and the All American Canal	IID (1999)
Los Angeles Aqueduct	DWR (1998a)

A complete listing of the various canals and pipelines summarized in the table above can be found in the "Appendix H- Facility Capacities Tables.xls" in the Appendix H folder, under the "Canal Capacities" worksheet. Facilities whose conveyance capacities were based on pumping capacity are listed in the next section on Pumping and Power Plants.

DWR

The predominant State Water Project conveyance facility in the state is the California Aqueduct. Other projects modeled by DWR include the North and South Bay Aqueducts, Pacheco Tunnel, the SWP East and West Branches, and the Friant-Kern system. No canal capacities were used on the South Bay Aqueduct, since flow is limited by the pumping capacity. Few capacities were used on the East and West Branches of the California Aqueduct, since pumping capacities provided sufficient bounds for the CALVIN model. All capacities used on DWR-operated conveyances in CALVIN were taken from the State Water Project Handbook (DWR 1997), with the exception of the Pacheco Tunnel in the San Felipe system, which used the Central Valley Project Reference Manual (DWR 1987). Losses on the California Aqueduct were modeled after DWRSIM Run 514 losses (DWR 1998b). A detailed description of the approach used to model the California Aqueduct in CALVIN can be found in "California Aqueduct.xls" file in the Appendix H folder.

USBR

Facilities operated by the USBR included the Delta Mendota Canal, Clear Creek Tunnel, the Cross Valley Canal, the Delta Cross Channel, the Folsom South Canal, Madera Canal, the Spring Creek Power Tunnel, and the Tehama-Colusa Canal. All of these conveyances were modeled using capacities listed in DWR (1997). Each of the reaches on the Friant Kern Canal, however, used capacities listed in the "Friant Kern Canal Structures List" (FWUA 1998), with the exception of the reach originating at Millerton Lake, which referenced DWR (1998a). Solano Irrigation District's Putah South Canal capacity data was derived from Rubin (1998). Finally, Kern County Water Agency facilities, specifically the Kern River Intertie, used constrained flows to match DWR (1998b) in all runs.

MWD Facilities

For pipelines owned and operated by the Metropolitan Water District (MWD), Upadhyay (1998) suggests lower capacities, the preferred capacities to be used by MWD.

The capacity on the MWD connection to the State Water Project through Castaic Lake is taken from DWR (1997). Capacities on the Lower and Upper MWD Feeders, the Rialto Pipeline, the Box Springs Feeder, and the Santa Ana Pipeline, were derived from the MWD (1997). The Inland Feeder, scheduled for completion in 2002, was assigned a capacity of 1000 cfs from MWD (1996). Facilities servicing the San Diego area include the San Diego Canal (MWD 1997) and San Diego Pipelines 1 through 6 (SDCWA 1998). San Diego Pipeline 6 is scheduled for completion in 2008.

The exits and entrances to the East Side Reservoir, as designated by the schematic vary greatly with reservoir head and direction of flow. For simplification, Upadhyay (1998) suggested 2800 and 2100 cfs as constraints for the exits and entrances, respectively.

SFPUC

CALVIN's representation of the Hetch Hetchy system, operated by the SFPUC, includes capacities on Lower Cherry Creek Aqueduct (155 cfs) and on the three San Joaquin pipelines (465 cfs). The addition of a proposed San Joaquin pipeline would bring the Hetch Hetchy Aqueduct's conveyance capacity up to 620 cfs. Hetch Hetchy capacities were taken from USBR (1987).

Other local facilities

Several local facilities play significant roles in the conveyance of water in the Bay Area, including releases from Los Vaqueros Reservoir for Contra Costa Water District (CCWD 1997), and the gravity-fed Mokelumne Aqueduct (EBMUD 1999).

In Southern California, local facilities include the Colorado River Aqueduct, the San Diego Aqueduct, Coachella Canal, the Los Angeles Aqueduct, and the All American Canal. Colorado River Aqueduct capacity was considered to be the Valverde Tunnel capacity of 1605 cfs (MWD 1997). San Diego Aqueduct capacity is 1800 cfs, based on DWR (1997).

Pumping and Power Plants

Table H-6 lists the pumping facilities modeled in CALVIN and the original sources for capacity estimates. Pumping plants are given considered fixed head, i.e. a fixed cost ($/af) cost is associated with the flow through the plant.

Table H-6. Pumping Plant Capacities

Location	Facility	Capacity	Source
California Aqueduct	Banks	10,300 cfs*	DWR 1997
California Aqueduct	Dos Amigos	11,800 cfs	DWR 1997
California Aqueduct	Buena Vista	5050 cfs	DWR 1997
California Aqueduct	Chrisman	4400 cfs	DWR 1997
California Aqueduct	Edmonston	4400 cfs	DWR 1997
California Aqueduct	Wheeler Ridge	4400 cfs	DWR 1997
California Aqueduct	Pearblossom (East Branch)	2932 cfs	DWR 1997
California Aqueduct	OSO (West Branch)	3129 cfs	DWR 1997
San Luis	Gianelli	11,000 cfs	DWR 1997
San Luis	O'Neill	4200 cfs	DWR 1987
Coastal Aqueduct	Los Perillas	450 cfs	DWR 1997
Coastal Aqueduct	Badger Hill	450 cfs	DWR 1997
Colorado Aqueduct	Colorado Aqueduct	1800 cfs	DWR 1998a
Delta Mendota Canal	Tracy	4600 cfs	DWR 1987
East Bay	Contra Costa Canal	300 cfs	Ohlemutz 1999
East Bay	Los Vaqueros	200 cfs	CCWD 1999
East Bay	Mallard Slough	50 cfs	Ohlemutz 1999
East Bay	Old River	250 cfs	Ohlemutz 1999
Mokelumne River Aqueduct	Walnut Creek	123 mgd	EBMUD 1999
MWD	Eastside	2100 cfs	Upadhyay 1998

South Bay Aqueduct	South Bay Aqueduct	330 cfs	DWR 1997
South Bay Aqueduct	Del Valle	120 cfs	DWR 1997

* 10,300 cfs, but hydraulic access and regulatory requirements limit actual operation to 6680 cfs from April thru November, and to 7590 cfs in Dec and Mar, and to hydraulic limit (without S.Delta improvements) to 8,500 cfs in Jan and Feb.

Colorado River Aqueduct capacities are taken directly from the State Water Project Handbook (DWR 1997). In some cases, these capacities represent downstream flow capacities. The capacity listed in Table H-6 for the Coastal Aqueduct pumps is 450 cfs, but DWR (1997) lists the Las Perillas Pumping Plant and Badger Hill Pumping Plant capacities at 461 cfs and 454 cfs, respectively.

Fixed-head powerplants are also included in CALVIN. They are modeled similary to pumping plants, except the fixed cost for flows through the powerplant link is negative. Only those powerplants which could reasonably be modeled as fixed-head are included in this initial study. Table H-7 lists these facilities.

Table H-7. Powerplant Capacities

Location	Facility	UpperBound	Source
All American Canal	All American Canal	10,155 cfs	IID 1999
California Aqueduct (East Branch)	Alamo	3149 cfs	DWR 1997
California Aqueduct (East Branch)	Devils Canyon	none used	n/a
California Aqueduct (East Branch)	Mojave	2876 cfs	DWR 1997
California Aqueduct (West Branch)	Castaic	18,000 cfs	DWR 1997
California Aqueduct (West Branch)	Warne	1564 cfs	DWR 1997
Los Angeles Aqueduct	Owens Valley 1	807 cfs	undocumented
Los Angeles Aqueduct	Owens Valley 2	780 cfs	DWR 1998a
San Luis	Gianelli	16,960 cfs	DWR 1997
San Luis	O'Neill	3900 cfs	DWR 1987

Supporting information detailing pumping and powerplant capacities can be found in “Constraints (1 to 3 with some 4).xls” and “Constraints 5.xls” in the Appendix H folder.

Agricultural and Urban Diversions

Since actual agricultural diversion capacities were often unknown, two distinct methods were used when modeling agricultural diversions and estimating their capacities. In the cases where known diversion capacities are used in CALVIN, these capacities were converted from cfs units to monthly varying upper bounds (in taf/mo). These capacities were used on only two agricultural diversions, both of which are off of the California Aqueduct in Region 4 (see Table H-8). Calculations in the “California Aqueduct.xls” file in the Appendix H folder were based on figures from the State Water Project Handbook (DWR 1997).

Where diversion capacities are unknown, the base case deliveries (Policy 4a) from the CVGSM No Action Alternative are used as the basis for estimating a maximum capacity on each agricultural surface water diversion throughout the state (also see Table Blobbity). Maximum monthly deliveries from the October 1921 to September 1993 time series that are greater than 100 taf/month were multiplied by 1.05 to estimate an upper bound capacity; maximum monthly deliveries less than 100 taf/month were multiplied by 1.10 to estimate an upper bound capacity. These agricultural diversions are distinguished from ground water pumping capacity. These calculations are outlined in the "CALVIN Ag & Urb SUPPLY CAPACITIES.xls" file in the Appendix H folder.

Table H-8. Agricultural Diversion Capacities

Ag Region	Origin Node	Source	Max flow (taf/mo)*
1	D5	Sacramento River at Keswick	7.3
1	D71	Whiskeytown Lake	4.6
1	D74	Sacramento River at DA58	25.3
2	C1	Misc. Left & Right Bank Diversions	1.8
2	C11	Tehema-Colusa Canal Diversions	0.7
2	C9	Black Butte Lake	26.4
2	D77	Corning Canal	12.5
3	C13	Glenn-Colusa Canal	198.1
3	C11	Tehema-Colusa Canal	71.4
3	C305	Colusa Basin Drain Diversions	36.7
3	D66	Sacramento River at DA15	54.9
4	D30	Sacramento River at DA15	194.6
5	C35	Bear River above Camp Far West Reservoir	8.7
5	C77	Feather River above Oroville	5.6
5	C80	Feather River	278.6
5	C83	Yuba River	68.2
5	D31	Sacramento River via drain RD1500	5.7
5	SR-6	Lake Oroville Releases	3.2
6	C16	Cache Creek at Capay Diversion Dam	36.3
6	C21	Putah South Canal	40.5
6	C314	Knights Landing Ridge Cut	32.1
7	C33	Bear River	33
7	C67	Sacramento River	49.1
7	D42	Feather River	3
8	C173	Folsom South Canal	6.7
8	C37	Cosumnes River	2.4
8	C43	Central San Joaquin ID from Stanislaus River	11
8	D98	Mokelumne Riparian Diversions	26.4
9	D507	Sacramento River	69.1
9	D515	Delta Cross Channel Diversion	46.8
9	D521	San Joaquin River	33.4
9	D523	San Joaquin River	73.5
10	C10	Lower San Joaquin River	40.8
10	C30	DMC Diversion	142.5
10	C85	Lower Cal. Aqueduct	27.5
10	D731	Upper San Joaquin River	118.1
10	D803	Upper Cal. Aqueduct	1.2
11	D16	Upper Stanislaus River	111.3

11	D662	Upper Tuolumne River	66
11	D664	Lower Tuolumne River	2.5
11	D672	Lower Stanislaus River	10
11	D689	San Joaquin River	3
12	D645	Upper Merced River	5.4
12	D649	Lower Merced River	12.2
12	D662	Upper Tuolumne River	107.1
12	D664	Lower Tuolumne River	2
12	D699	San Joaquin River	4.5
13	C72	Madera Canal/Millerton	89.5
13	D606	Upper San Joaquin River	2.2
13	D624	Fresno River	57.2
13	D634	Chowchilla River	42.9
13	D645	Upper Merced River	111.4
13	D649	Lower Merced River	4.3
13	D694	Lower San Joaquin River	0.5
13	D731	San Joaquin River, Mendota Pool	10.3
14	C92	California Aqueduct	232.8
14	D608	Mendota Pool	4.9
15	C54	Kings River	461
15	C56	Kaweah River	29.7
15	***C75***	***California Aqueduct***	***1236 cfs****
15	D608	Mendota Pool	17
16	C49	Friant Kern Canal	6.8
16	C53	Kings River	130.2
16	D606	San Joaquin River	2.2
17	C53	Kings River	217.4
17	C76	Friant Kern Canal	12.9
18	C56	Kaweah River	179.6
18	C58	Tule River	23.1
18	C688	Friant Kern Canal	172.3
19	C62	Friant Kern Canal	3.5
19	C97	Kern River	84.7
19	***D850***	***California Aqueduct***	***3957 cfs****
20	C64	Friant Kern Canal	69.4
20	C65	Kern River	79.2
21	C689	Friant Kern Canal	28.8
21	C74	Cross Valley Canal	30.6
21	C97	Kern River	135.5
21	C98	California Aqueduct	98.1

* Where noted, agricultural diversion capacities are listed in cfs.

The three Southern California agricultural demand regions included in CALVIN (Coachella Valley, Imperial Valley, and Palo Verde) are modeled somewhat differently, since they are not modeled in CVGSM. Diversion capacities to these regions were limited by capacities on their supplies. Supplies to Coachella Valley are limited by the physical capacity of the Coachella Canal. Likewise, supplies to Imperial Valley are limited by the capacity of the All American Canal. Palo Verde supplies are limited by water available from the Colorado River.

Each agricultural diversion is modeled using two links in CALVIN. The link from the origin node to a hidden node contains the flow capacity shown in the above table. Another link from the hidden node to the farm gate models losses on the diversion through the use of an amplitude of less than one. This amplitude is the same for all agricultural supplies for a given agricultural demand region, and represents the average loss rate from both recoverable and non-recoverable losses. Most loss rates were originally obtained from CVGSM NAA 1997 input files, but diversions for CVPM 14, 15, 19, and 20 were derived from DWRSIM Run 514 loss rates. These figures were adapted for use in CALVIN in the "CVGSM Diversions 2 edMJ 101900.xls" and "CVPMBasinWideWaterBal.xls" files in the Appendix H folder.

Urban supplies are conveyed by a combination of dedicated facilities (such as the Los Angeles Aqueduct serving Metropolitan Water District), and diversions from facilities which service more than one user in CALVIN. Dedicated conveyance structure capacities are listed in the Canals and Pipelines section of this appendix. Table H-9 contains diversion capacities for urban demand regions throughout the state that are modeled in CALVIN. As with agricultural diversions, these capacities represent aggregated diversion capacities, since modeling each diversion in detail adds significant and unnecessary complexity to the model.

Table H-9. Urban Diversion Capacities

Urban Area	Supply Source	Capacity	Source
Antelope Valley	California Aqueduct (East)	830 cfs	DWR (1997)
Antelope Valley	California Aqueduct (West)	35 cfs	DWR (1997)
Bakersfield	California Aqueduct	12 taf/mo	estimated
Central MWD	MWD Feeders	1500 cfs	MWD (1997)
Central MWD	Rialto Pipeline/ Box Springs Feeder	1116 cfs	MWD (1997)
Central MWD	Castaic Lake	3500 cfs	DWR (1997)
E&W MWD	Auld Valley Pipeline	340 cfs	MWD (1996)
Mojave	California Aqueduct (East)	0	estimated
Sacramento	Sacramento River	10.3 taf/mo	Reg 1 to 4 Urban**
Sacramento	South Fork American River	20.1 taf/mo	Reg 1 to 4 Urban**
Sacramento	Folsom Lake	44.7 taf/mo	Reg 1 to 4 Urban**
San Bernardino	California Aqueduct (East)	238 cfs	DWR (1997)
San Diego	Tijuana Canal	0	proposed
San Diego	San Diego Pipelines 1 to 4	885 cfs	SDCWA (1998)
San Diego	San Diego Pipelines 5 and 6	970 cfs	SDCWA (1998)
Santa Clara Valley	Hetch Hetchy	13.5 taf/mo*	Reg 1 to 4 Urban**

* Capacity on Hetch Hetch transfers to SCV has inadvertently been set too high. Maximum transferability is listed to be 76 taf/yr, or 6.33 taf/mo.
** Reg 1 to 4 Urban is shortened from "Region 1 to 4 Urban Documentation.xls"

Detailed information and modeling approaches are outlined in "Region 1 to 4 Urban Documentation.xls", and "Region 5 Urban Documentation.xls". "Urb Diversions.xls" may also be a useful reference. These files can be found in the Appendix H folder of the Software and Data Appendices.

Recycling Facilities

Table H-10 lists the recycling facilities included in the CALVIN model. Each of these facilities services an urban area. Facilities that are listed at zero capacity indicate that no recycling capacity is expected in the year 2020.

Table H-10. Recycling Facilities

Description	Link	Capacity	Source
Contra Costa WD	T18_T16	20 taf/yr	DWR (1998)
East Bay MUD	T35_T17	22 mgd	http://www.ebmud.com
Sacramento	T13_T4	6 mgd	Montgomery Watson (1998)
Stockton	T27_T26	0	DWR (1998)
Santa Clara Valley	T19_T7	16 taf/yr	SCVWD (1997); ACWD (1995)
Bakersfield	T29_T28	0	DWR (1998)
Fresno	T25_T24	0	DWR (1998)
Antelope Valley	T33_T6	6 taf/yr	DWR*
Central MWD	T10_T5	0	DWR (1998)
Coachella	T11_T31	15 taf/yr	DWR (1998)
E/W MWD	T12_T34	0	DWR (1998)
Mojave	T32_T3	6 taf/yr	DWR (1998)
San Diego	T8_T30	0	DWR (1998)
San Bernardino Valley	T9_T2	12 taf/yr	SBVMWD (1995)

*Recycling value for Antelope Valley was derived from detailed PSA listings from the Department of Water Resources. See "Reg 5 Urban Documentation.doc" for further details.

Two cost levels were applied to recycling facilities throughout the state. On the facilities for the two MWD urban areas and the San Diego urban area, recycling costs were estimated to be $850/af due to higher-end uses. Otherwise, a cost of $350/af was used on all other recycling facilities. These cost levels are discussed in Appendix G.

EBMUD reclaimed water production in 1998 was 14.57 mgd and an additional 8.1 mgd is planned for 2020 for a total of 22.7 mgd. The assumption for CALVIN is that an upper bound of 2.12 taf/month is the 2020 capacity for reclamation, based on 22.7 mgd for an average of 30.5 days/month. No specific cost data for EBMUD reclamation was found so that the default state-wide variable O&M cost is used (see Appendix G: Operating Costs). Recycling in the Sacramento urban region only occurs in City of Roseville at a rate of 6 mgd recycled water plant (Montgomery Watson 1998). There is no planned additional capacity for 2020 in Greater Sacramento urban area.

In the Santa Clara Valley urban demand region, a total recycling capacity of 16 taf/yr is planned for the year 2020. 14.4 taf/yr of that capacity will be in the Santa Clara Valley Water District, and the remaining 1.6 taf/yr in the Alameda County Water District.

According to the 1993 water budget accounting by DWR, reclamation in the Antelope Valley PSA in the South Lahontan hydrologic region, corresponding to the Antelope Valley urban area in CALVIN, was 6 taf/yr. The 1993 DWR water budget indicates that the Mojave River PSA (the Mojave urban region in CALVIN) reclaimed 6 taf/yr in 1993. No projected increases in recycling are planned for 2020 (DWR 1998). In addition, in 1993 there was 6 taf/yr of reclamation reported in the DWR water budget accounting for Coachella PSA in the Colorado River hydrologic region.

Central and E/W MWD recycling, as well as San Diego, were listed at zero capacity in CALVIN. Existing recycling is already included in the surface deliveries, and no additional capacity is anticipated for the year 2020 (DWR 1998). See the "Reg 5 Urban Documentation.doc" for further information.

Much of this documentation regarding the capacities and locations of these various recycling facilities has been taken from "Reg 1 to 4 Urban documentation.doc" and "Reg 5 Urban Documentation.doc" under Appendix H in the Software and Data Appendices folder. Further details can be found in these supporting files.

Groundwater Pumping and Recharge

This section outlines four groundwater facility considerations within CALVIN: pumping for fixed urban demands, pumping for economic urban demands, agricultural pumping, and recharge facilities included in CALVIN. Appendix G contains supporting information on how groundwater pumping costs were calculated for each of the basins.

As outlined in Appendix E of this report, urban areas within the Central Valley that have utilize groundwater exclusively were often able to be modeled using fixed demands. Groundwater pumping for these urban demands was constrained using time series to fully meet projected demand. Refer to Appendix E and the "GWpump.xls" file for more information on how projected fixed urban demands were derived.

Pumping for Economic Urban Demands

In contrast to agricultural pumping data, information regarding pumping for urban areas modeled economically in CALVIN came almost entirely from local studies (the exceptions being Stockton and Bakersfield). Volumes of detailed information needed to be condensed into aggregated urban demand areas. The underlying assumptions behind urban aggregation are explicitly outlined in "Reg 1 to 4 Urban Documentation.xls" and "Reg 5 Urban Documentation.xls" in the Appendix H folder. Figures which have been updated since the completion of these two supporting files are explained in this section.

Accurate modeling of these urban demand areas often required an estimate of their maximum pumping capacities. Table H-11 lists the urban pumping facilities with capacities, and the sources from which those figures came. Again, refer to the supporting Excel files for a detailed outline of the modeling approach to each of these capacities.

Table H-11. Pumping Capacities for Urban Economic Demand Areas

Urban Area	Capacity (taf/mo)	Source
Sacramento (GW-7)	31.3	ARBCA 1998

Sacramento (GW-8)	17.5*	Sacramento 1995; Water Forum 1997
Stockton	10	DWR 1994
Santa Clara Valley	30.5	SCVWD 1999; Zone 7 1999; ACWD 1999
Bakersfield	33	DWR 1994
Owens Valley	10	Inyo 1990
Metropolitan Water District	146	MWD 1996

* supporting documentation indicates this value may actually be 15.5 taf/mo

The City of Sacramento is serviced by two groundwater basins: the basin named GW-7 in CALVIN for the area north of the American River, and GW-8 for the area to the south of the American River. Capacity information was gathered on 16 communities north of the American River (estimates were made for several communities where pumping capacity could not be obtained) and then translated into a monthly pumping capacity out of GW-7. A similar analysis was made for five communities south of the American River and west to the Delta that utilized GW-8. The figure of 15.5 taf/mo calculated in the supporting file was later revised to 17.5 for an undocumented reason.

The Santa Clara Valley pumping capacity was compiled from data obtained from the Santa Clara Valley Water District, Alameda County Water District, and Alameda County Zone 7. Initial calculations resulted in an estimate of 35.8 taf/mo pumping capacity, though this figure was later revised down to 30.5 taf/mo since none of the three agencies are known to use groundwater for more than 50% of their supply (see "Reg 1 to 4 Urban Documentation.xls").

The capacity for Bakersfield was calculated to be 22.6 taf/mo from DWR (1994) information, but was later revised to 33 taf/mo after the former capacity resulted in false scarcities. The pumping capacities for Owens Valley and Metropolitan Water District were estimated from local studies. Stockton uses an undocumented pumping capacity of 10 taf/mo, though the supporting file ("Reg 1 to 4 Urban Documentation.xls") lists 9.6 taf/mo.

Several urban demand areas did not utilize a pumping capacity in the CALVIN runs. For Antelope Valley, no limit is placed on groundwater pumping capacity so that cost, usable storage capacity and end-of-period storage will dictate use (since there is a lack of accurate information on what the urban pumping capacity will be in 2020). Fresno does not have a pumping capacity, though the reasoning for this is undocumented. The estimated current pumping capacity of 155 KAF/yr in Coachella is well below the 600 KAF/yr projected 2020 urban demand in CALVIN. Since there is not plan to switch to surface water and treatment, the assumption in CALVIN is that pumping capacity will increase with demand and is therefore unlimited for the Coachella urban region.

Agricultural Pumping

Agricultural pumping capacities for CVPM 1 to 21 were estimated by adding 10% to the maximum monthly pumping rate for each of the regions if that maximum rate was over 100 taf/mo, and adding 5% if less than 100 taf/mo. Pumping capacities for the Imperial and Coachella Valleys were estimated from recharge (see Appendix G). Table H-12 lists these groundwater pumping capacities.

Table H-12. Agricultural Pumping Capacities (taf/mo)

Region	Capacity
CVPM 1	20.8
CVPM 2	153.2
CVPM 3	171.0
CVPM 4	110.5
CVPM 5	225.7
CVPM 6	148.1
CVPM 7	96.0
CVPM 8	208.4
CVPM 9	73.8
CVPM 10	197.9
CVPM 11	52.2
CVPM 12	80.6
CVPM 13	291.0
CVPM 14	332.9
CVPM 15	407.9
CVPM 16	60.8
CVPM 17	152.4
CVPM 18	385.0
CVPM 19	171.1
CVPM 20	108.1
CVPM 21	228.3
Imperial Valley	5.0
Coachella Valley	5.0

Future modeling efforts should include minimum pumping capacities as well to account for irrigated areas with no access to surface water. These minimum capacities were not used in the set of CALVIN runs described in this report.

Recharge

The recharge considered in this section is artificial recharge of groundwater basins from surface water sources, including wastewater treatment plant discharges, but not incidental deep percolation of applied urban water or incidental infiltration of wastewater discharges along streams. The predominant method appears to be mainly percolation ponds. Surface sources for artificial recharge include SWP water, CVP water, local watershed runoff, and a portion of wastewater treatment plant discharges. Table H-13 shows the artificial recharge facilities included in CALVIN and their original source documentation.

Table H-13. Artificial Recharge Capacities

Recharge facility	Capacity	Source
Owens Valley	15 taf/mo	Inyo 1990
Mojave	375 cfs	DWR 1997
Coachella	10 taf/mo	undocumented

Metropolitan Water District	45 taf/mo	undocumented
Santa Clara Valley	20 taf/mo	SCVWD (1997); Zone 7 (1999)

Santa Clara Valley artificial recharge capacity includes figures gleaned from SCVWD and Zone 7 local studies (referenced above), as well as an estimated recharge capacity for Alameda County Water District (1.25 taf/mo). A conservative estimate of 10 taf/yr was used for Zone 7 was taken from the Zone 7 web site (Zone 7 1999). Santa Clara Valley Water District anticipates an increase in artificial recharge capacity from 157 taf/yr to nearly 204 taf/yr by 2020 (SCVWD 1997). See "Reg 1 to 4 Urban Documentation.xls" for more details.

A number of other recharge links have been included in CALVIN but have been constrained to zero capacity. Artificial recharge facilities in areas such as Napa-Solano, Sacramento, and Imperial Valley are anticipated to have minimal capacity in the year 2020. Including them in the model, however, forces CALVIN to generate marginal values of increasing recharge capacity in various locations in the system.

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