APPENDIX A

CLIMATE CHANGE SURFACE AND GROUNDWATER HYDROLOGIES FOR MODELING WATER SUPPLY MANAGEMENT

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ABSTRACT

Global warming has significant impacts on hydrologic processes in terms of water availability and quality. Several studies have been done on California's hydrologic response to climate change. Most studies indicate that California may have more winter runoff and less summer runoff throughout the next century. However, almost all these studies focus exclusively on changes in streamflow in a few rivers. Based on projected streamflow ratios of six index basins and statewide temperature shifts, along with precipitation change ratios for 12 climate change scenarios developed by Lawrence Berkeley National Laboratory, climate-perturbed 72 year historical monthly hydrological time series of rim inflows, reservoir evaporation rates, local surface water accretions, and groundwater inflows were generated for California's intertied water system. Various analyses of the perturbed hydrological time series have been done and the statistics show that the perturbed hydrology can be a reasonable hydrologic representation of the 12 climate scenarios. The perturbed hydrology will form a basis for water supply system planning and management studies using the CALVIN economic engineering optimization model. Without operation modeling, approximate changes in water availability are estimated for the 12 climate change scenarios. These changes are compared with estimated changes in urban and agricultural water use between now and 2100.

INTRODUCTION

This attachment discusses California's hydrology under projected climate changes. Monthly streamflow incremental ratios at six index basins, statewide temperature shifts, and precipitation changes were used to perturb CALVIN hydrology. Lawrence Berkeley National Laboratory (LBNL) developed these ratios and shifts (Miller et al., 2001). The CALVIN hydrology consists of 72 year (October 1921 through September 1993) monthly time series of rim inflows, reservoir evaporation rates, local accretions, and groundwater inflows. Excel VBA-based object-oriented software was developed to calculate the climate-perturbed CALVIN hydrology for different combinations of CALVIN regions, hydrological components, mapping methods, and climate scenarios.

This attachment begins with an overview of general climate change issues and California's historical climate and then introduces projected California climate scenarios developed by LBNL. In following sections, methods and results of perturbed rim inflows, reservoir evaporation rates, local surface accretions, groundwater inflows, total quantities, and water availabilities are presented, and the strengths and weakness of each part are discussed. At the end of the attachment, several tables are presented to show the spatially distributed results for each inflow and reservoir location.

General Climate Change Issues

Research in several areas of geology indicates that climate has changed throughout the history of our planet (Dam, 1999). The latest 2001 Intergovernmental Panel on Climate Change (IPCC) report reaffirms that climate is changing in ways that cannot be accounted for by natural variability and that “global warming” is occurring (IPCC, 2001). The major cause of warming is thought to be from human activity — primarily the use of fossil fuels — changing the composition of the atmosphere.

The IPCC reports that climate model projections with a transient 1% annual increase in greenhouse gas emissions show an increase in the global mean near-surface air temperature. The temperature increase ranges from 1.4°C to 5.8°C, with a 90% probability interval of 1.5°C to 4.5ºC by 2100 (Wigley and Raper, 2001). This projected change is larger than any climate change experienced in the last 10,000 years.

Climate change has several influences on hydrology. The main components of the hydrologic cycle are precipitation, evaporation, and transpiration. Changes in the climate parameters — solar radiation, wind, temperature, humidity, and cloudiness — will affect evaporation, transpiration, and the form of precipitation. Changes in evapotranspiration and precipitation will affect the amount, as well as the temporal and spatial distribution of soil moisture and surface runoff. As global and regional temperatures increase, there will be changes in rainfall patterns throughout the world, increases in evaporation rates, and changes in hydrologic variability (Dam, 1999). Modeling studies of the association between climate change and water resources have focused particularly on the relationships between streamflow, precipitation, and temperature (Risbey and Entekhabi, 1996).

Climate change might influence the hydrologic cycle at different temporal and spatial scales. The driving meteorological variables can be estimated from general circulation model (GCM) scales. Assessing climate change and its likely impacts on the hydrologic cycle is extremely complex. Several global and regional scale studies have been done (Lettenmaier and Gan, 1990; Nijssen et al., 2001). Likely changes during the 21st century include higher maximum and minimum temperatures, more intense precipitation events, increased summer drying, and increased risk of drought and flood.

California Climate and Historical Climate Change

California climate and hydrology

Water is scarce in California. The state has a nice Mediterranean climate, with cool wet winters and warm dry summers, but a water supply that is poorly distributed in both time and space. On average, half the annual precipitation occurs in the three months of December, January, and February. Three-fourths occurs in the 5 month period from

November through March. The only significant departures are in the dry southeastern desert areas, which have a summer monsoon peak as well as a winter season maximum.

In California the wetter regions contributing most of the runoff are in the north. Most demand for water is in the central and southern portions of the state. Three-fourths of the state's 71 million acre-feet (maf) of average natural runoff originates north of Sacramento; about 80% of urban and agricultural water demand is south of Sacramento (Roos, 2002).

Historical Climate

To understand how future climate change will affect water resources, it is important to understand historical climate.

The Sierra Nevada mountains are California's most important catchment area, providing two-thirds of the state's developed surface water supply. Until recently, the most severe and persistent drought of California's historical record occurred between 1928 and 1934, when runoff was below average (Department of Water Resources, 1994). However, Stine (1994) studied the tree stumps rooted at four present day sites in the Sierras (Mono Lake, Tenaya Lake, the West Walker River, and Osgood Swamp), which suggested that California's Sierra Nevadas experienced extremely severe drought conditions for more than two centuries before A.D. ~1112 and for more than 140 years before A.D. ~1350. During these periods, runoff from the Sierra Nevadas was significantly lower than during any of the persistent droughts in the region during the past 140 years. Stine suggested that the droughts might have been caused by reorientation of the midlatitude storm tracks, a general contraction of circumpolar vortices, a change in the position of the vortex waves, or all three. If this reorientation was caused by medieval warming, future warming from natural or anthropogenic sources warming may cause a recurrence of such extreme drought conditions.

Stine (1994) noted that the findings support the notion that the medieval climate anomaly was a global phenomenon and that the aberrant atmospheric circulation of medieval times seems to have brought to some regions of the world a far greater departure in precipitation than in temperature. California's medieval precipitation regime, if it occurred with today's burgeoning human population, would be highly disruptive environmentally and economically. This emphasizes the importance of considering changes in precipitation, rather than simply in temperature, when weighting the potential impacts of future global climate change.

Stine (1996) also examined the Sierra Nevada climate from 1650 through 1850. His main conclusions were

- ► Growing-season temperatures reached their lowest level of the past millennium around 1600 and then remained low, by modern (1928-1988) standards, until around 1850

- ► The period from 1713 to 1732 was, by modern standards, characterized by relatively wet conditions. It was preceded by a century dominated by low precipitation, and followed by 130 years (particularly the intervals from 1764 to 1794 and 1806 to 1861) of anomalous drought

► The period from 1937 to 1986 has been the third-wettest half-century interval of the past 1,000 years.

To gain a long-term perspective on hydrologic drought, Meko et al. (2001) reconstructed Sacramento River annual flow back to A.D. 869 from tree rings.. The results suggest that persistent high or low flows over several decades characterize some part of the long-term flow history. The reconstruction supported using the 1930s as a design period of extreme drought with duration of perhaps 6 to 10 years. Because Meko's reconstruction of Sacramento River system runoff does not match the severity of the Stine droughts, we are not sure how widespread they were.

California Projected Climate by LBNL

The spatially distributed California flow impacts of climate change presented in this attachment are based on streamflow estimates for six California basins that Miller et al. (2001) generated for 12 climate scenarios.

Climate scenarios and the hydrologic model

Because of the uncertainty inherent in projecting future climate, Miller et al. (2001) applied a range of potential future climatological temperature shifts (1.5ºC, 3.0ºC, and 5.0ºC) and precipitation changes (0%, 9%, 18%, and 30%) to the National Weather Service River Forecast System (NWSRFS) Sacramento Soil Moisture Accounting (SAC-SMA) Model and Anderson Snow Model to assess hydrologic sensitivities. Two GCM projections for three projected future periods (2010-2039, 2050-2079, and 2080-2099) were also used in this analysis; one projection is warmer and wetter (the Hadley Climate Centre's HADCM2 run 1) and one is cooler and drier (parallel climate model [PCM] run B06.06), relative to the GCM projections that were part of the IPCC's Third Assessment Report (Miller et al., 2001). The IPCC projections were statistically downscaled to a 10 km spatial resolution and a month-to-month temporal resolution, which more tightly focused the global climate change data onto California. Finally, the NWSRFS SAC-SMA model was used to estimate the impacts of these average monthly temperature and precipitation projections on six California watersheds. This hydrologic model system estimates how temperature and precipitation contribute to soil moisture, snowpack, snowmelt, and ultimately streamflow. The model system was specifically chosen because it is the operational model used by the NWS, meaning that it has considerable empirical validity and has received scrutiny over a significant period of time.

The 12 climate scenarios include:

1. 1.5ºC temperature increase and 0% precipitation increase (1.5 T 0% P)
2. 1.5ºC temperature increase and 9% precipitation increase (1.5 T 9% P)
3. 3.0ºC temperature increase and 0% precipitation increase (3.0 T 0% P)
4. 3.0ºC temperature increase and 18% precipitation increase (3.0 T 18% P)

5. 5.0ºC temperature increase and 0% precipitation increase (5.0 T 0% P)
6. 5.0ºC temperature increase and 30% precipitation increase (5.0 T 30% P)
7. HADCM2 2010-2039
8. HADCM2 2050-2079
9. HADCM2 2080-2099
10. PCM 2010-2039
11. PCM 2050-2079
12. PCM 2080-2099.

Geographic and hydrologic characteristics of the six index basins

Miller et al. (2001) chose six representative headwater basins (Smith River at Jed Smith State Park, Sacramento River at Delta, Feather River at Oroville Dam, American River at North Fork Dam, Merced River at Pohono Bridge, and Kings River at Pine Flat Dam) with natural flow for analysis in this study (Figure 1). The six California basins stretch from the northernmost area to the east-central region of the state.

Fig 1. Location of the six index basins (Miller et al. 2001)

Table 1 shows basin size, location, and percentage area of upper sub-basin, as well as the centroid of each upper and lower sub-basin. The gauge name, gauge latitude and longitude, and elevation of each corresponding CALVIN rim inflow location also are shown in Table 1 for comparison purposes. Among the six index basins, the Smith is a very wet coastal basin that does not significantly accumulate seasonal snowpack. The Sacramento is a mountainous northern California basin with a small amount of seasonal snow accumulation. The Sacramento provides streamflow for the north and northwest drainage region into the Central Valley. The Feather and the Kings represent the northernmost and southernmost Sierra Nevada basins for this study, and the Kings and Merced are the highest elevation basins. The American is a fairly low-elevation Sierra Nevada basin, but frequently exceeds flood stage, resulting in substantial economic losses. This set of study basins provides fairly broad information for spatial estimates of the overall response of California's water supply (excluding the Colorado River) and will help indicate the potential range of hydrologic impacts. Figure 2 shows the CALVIN model's 72 inflow and local accretion locations, 47 reservoir locations, and 28 groundwater basins' centroid in the five modeled regions.

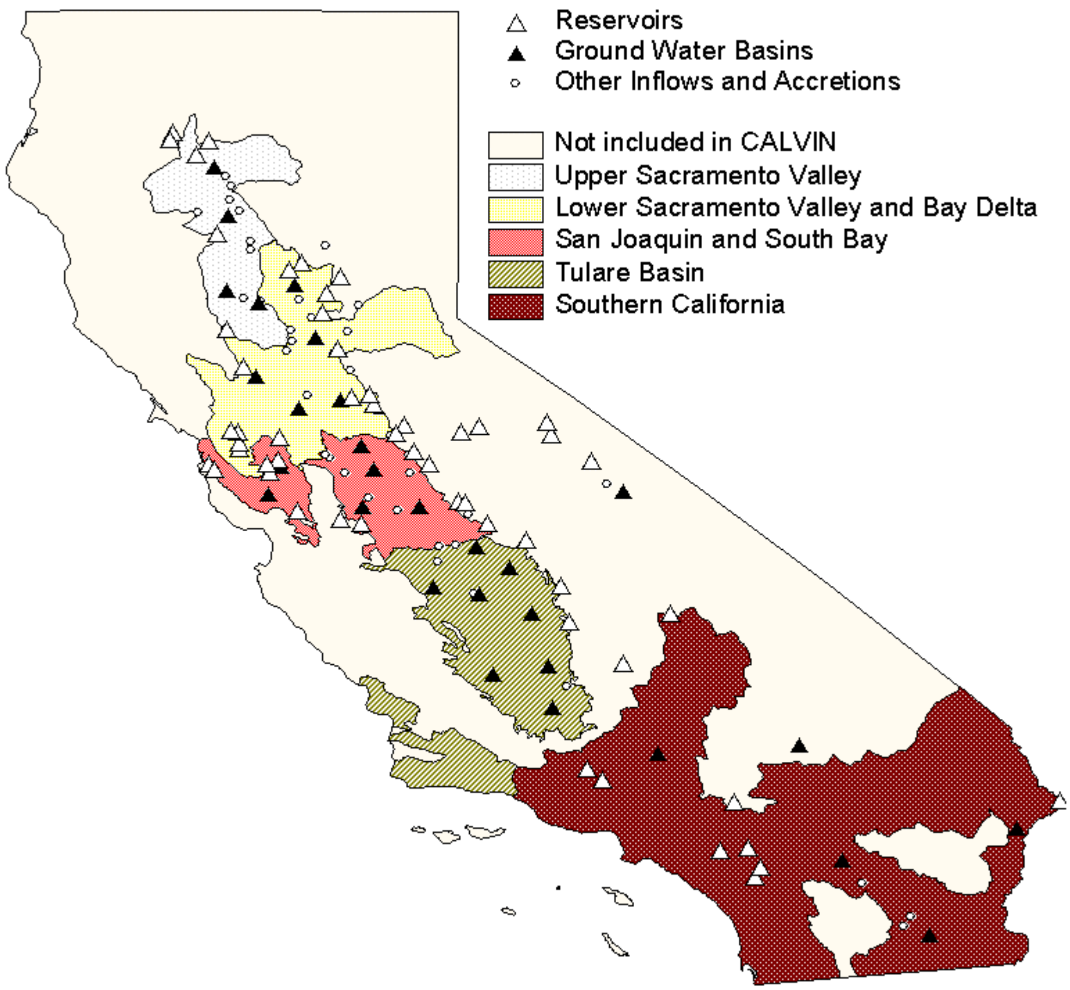

Fig. 2 CALVIN modeled demand regions, inflows, and reservoirs

Table 1. Comparison of index basins and corresponding CALVIN rim inflow locations.

Basin/inflow location		Smith	Sacramento	Feather	American	Merced	Kings
LBNL index basin (Miller et al., 2001)	Area	1706 km^2	1181 km^2	9989 km^2	950 km^2	891 km^2	4292 km^2
	Gage latitude	41º 47’ 30” N	40º 45’ 23” N	39º 32’ 00” N	38º 56’ 10” N	37º 49’ 55” N	36º 49’ 55” N
	Gage longitude	124º 04’30” W	122º 24’ 58” W	121º 31’ 00” W	121º 01’ 22” W	119º 19’ 25” W	119º 09’ 25” W
	Percent upper[a]	0	27	58	37	89	72
	Upper centroid[b]	N/A	1798	1768	1896	2591	2743
	Lower centroid[c]	722	1036	1280	960	1676	1067
CALVIN rim inflow location	Location	N/A	Shasta Lake	Oroville Lake	Folsom Lake	Lake McClure	Pine Flat Reservoir
	Gage latitude	N/A	40° 43’ 01’’ N	39º 32’ 00” N	38°42’00’’ N	37º 35’ 02” N	36º 49’ 51” N
	Gage longitude	N/A	122° 25’ 01’’W	121º 31’ 00” W	121° 10’ 01’’W	120º 16’ 01” W	119º 20’ 06” W
	Gage elevation	N/A	1075 ft	300 ft	466 ft	867 ft	557 ft

a. Area percentage of upper sub-basin.
b. Elevation of upper sub-basin centroid.
c. Elevation of lower sub-basin centroid.

Summary of LBNL Results for Index Basins

For each climate change scenario, runoff was calculated for the six California index basins that extend from the coastal mountains and northern Sierra Nevada region to the southern Sierra Nevada region. For all scenarios, a larger proportion of the annual streamflow volume occurs earlier in the year because of fewer freezing days during the winter months. The amount and timing of changes depend on the characteristics of each basin, particularly the portion of drainage above the elevation of the freezing line. The hydrologic response varies for each scenario and the resulting solution set provides bounds to the range of likely changes in streamflow, snowmelt, snow water equivalent, and the change in the magnitude of annual high flow days. Table 2 shows annual and seasonal changes compared to the historical streamflow of each basin for each climate change scenario.

Table 2. Average percent changes of index basin runoff compared with historical data

Scenario	Smith			Sacramento			Feather			American			Merced			Kings		
	An- nual	**Oct.- Mar.**	**Apr.- Sep.**	**An- nual**	**Oct.- Mar.**	**Apr.- Sep.**	**An- nual**	**Oct.- Mar.**	**Apr.- Sep.**	**An- nual**	**Oct.- Mar.**	**Apr.- Sep.**	**An- nual**	**Oct.- Mar.**	**Apr.- Sep.**	**An- nual**	**Oct.- Mar.**	**Apr.- Sep.**
1	-6.9	-6.4	-9.2	-6.0	6.0	-24.7	-3.6	15.5	-30.8	-6.6	8.5	-29.5	-7.5	62.2	-21.1	-5.3	9.5	-10.9
2	3.5	4.7	-1.2	6.2	20.5	-16.2	9.9	31.7	-21.2	7.7	25.6	-19.6	6.8	88.1	-9.2	7.5	24.8	0.9
3	-7.0	-6.4	-9.3	-5.3	16.8	-39.7	-3.0	28.9	-48.2	-7.0	19.5	-47.4	-8.3	151.2	-39.6	-4.0	37.7	-19.9
4	13.8	15.6	6.4	19.4	48.8	-26.6	24.5	66.8	-35.8	22.0	57.7	-32.6	20.0	225.1	-20.2	22.0	75.6	1.6
5	-7.0	-6.5	-9.3	-5.0	22.7	-48.2	-3.8	33.9	-57.4	-8.2	23.9	-57.0	-9.9	262.4	-63.3	-2.2	90.2	-37.5
6	27.7	30.4	16.8	36.4	80.1	-31.8	42.1	102.0	-43.0	40.6	92.7	-38.8	37.3	443.3	-42.3	41.0	175.7	-10.4
7	12.4	13.7	7.0	19.5	36.6	-7.4	31.2	59.5	-9.0	34.3	55.3	2.2	35.1	127.3	17.0	39.2	59.5	31.5
8	17.4	23.1	-6.1	27.1	56.8	-19.2	43.3	88.1	-20.3	47.5	86.5	-12.0	47.1	227.7	11.7	51.3	101.2	32.3
9	35.4	43.8	1.0	49.3	96.9	-24.8	71.9	143.5	-29.8	76.1	141.1	-22.9	81.2	417.3	15.3	99.7	202.1	60.6
10	-14.9	-16.8	-6.9	-14.4	-15.3	-13.1	-12.7	-11.4	-14.5	-11.8	-12.0	-11.5	-7.3	11.0	-10.9	-9.9	-5.6	-11.5
11	-20.2	-21.3	-15.9	-18.8	-10.8	-31.4	-17.2	-3.1	-37.2	-22.1	-12.3	-36.9	-24.0	13.7	-31.4	-19.8	-8.4	-24.2
12	-25.5	-28.4	-13.6	-27.5	-18.9	-40.9	-30.5	-15.9	-51.1	-36.2	-26.8	-50.5	-38.9	26.4	-51.7	-32.5	-13.1	-39.9
Historica l (maf)	2.87	2.31	0.57	0.92	0.56	0.36	4.68	2.75	1.93	0.61	0.37	0.24	0.50	0.08	0.42	1.84	0.51	1.33

Source: Miller et al., 2001.

Other Views of Climate Change for California

In many cases and in many locations, there is compelling scientific evidence that climate changes will pose serious challenges to California's water system (Wilkinson, 2002). Several investigations of California's hydrologic response to climate change have focused on changes in streamflow volumes and timing. In general, these studies suggest that Sierra Nevada snowmelt-driven streamflows are likely to peak earlier in the season under global warming.

Lettenmaier and Gan (1990) studied the hydrological sensitivity of four medium-sized mountainous catchments in the Sacramento-San Joaquin River Basins to long-term global warming. The selected catchments were: (1) McCloud River near McCloud (USGS 11-3675; 358 square miles); (2) Merced River at Happy Isles Bridge (USGS 2645; 187 square miles); (3) North Fork of the American River at North Fork Dam (USGS 11-4170; 342 square miles); and (4) Thomes Creek at Paskenta (USGS 11-3820; 203 square miles).

To simulate the hydrologic responses of these snowmelt-driven catchments, snowmelt and soil moisture accounting models from the NWSRFS were coupled. In all four catchments, the global warming pattern indexed to carbon dioxide (CO_2) doubling scenarios simulated by three GCMs produced a major seasonal shift in the snow accumulation pattern. The conclusions were that: (1) the general warming simulated by all the GCMs under CO_2 doubling would substantially decrease average snow accumulations in all studied catchments; (2) reduction in precipitation occurring as snow would increase winter runoff and decrease spring and summer runoff; and (3) increased precipitation occurring as rainfall in the winter months would increase winter soil moisture storage and would make more moisture available for evapotranspiration (ET) in the early spring. Increased temperatures would increase spring ET.

CALVIN RIM INFLOWS

The CALVIN model has 37 inflows into the Central Valley from the surrounding mountains, which are called rim inflows. Historically, these rim inflows average 28.2 maf/yr, accounting for 72% of all inflows into CALVIN's California intertied water system. The basic idea of rim inflow perturbation is to map hydrologic regime changes of the six index basin streamflows to the 37 CALVIN basin rim inflows.

Mapping Method

To map the appropriate incremental ratios to CALVIN rim inflows, several methods were tried and some lessons were learned. In addition, some satisfactory results were obtained. It proved almost impossible to find reasonable matches for all the CALVIN inflows with only one method. The various statistical approaches to identify corresponding index basins for each CALVIN inflow include:

1. maximum annual flow correlation coefficient between CALVIN inflows and index basin flows
2. maximum monthly flow correlation coefficient between CALVIN inflows and index basin flows

3. multiple regression mapping by year
4. multiple regression mapping by month
5. wet and dry seasons (October to March and April to September) least sum of squared error (SSE) of monthly percentage distribution of annual flow
6. visual comparison (by runoff monthly distributions, gage geographic locations, and hydrologic processes - snowmelt runoff or not).

Finally, methods (1), (5), and (6) were combined to establish a 37×2 mapping matrix to identify the most appropriate index basins for wet and dry seasons for each CALVIN rim inflow. With method (6), the monthly rim inflow incremental ratios of some index basins were shifted forward or backward by 1 month, representing snowmelt timing changes to obtain the best fit for CALVIN inflow locations on the east side of the Sierras.

For the maximum correlation coefficient criterion, annual rim inflow correlation coefficients were calculated between each index basin and each CALVIN rim inflow for the water years from 1963 to 1993. Miller et al. (2001) simulated the six index basin flow series. The rim inflow series are taken from CALVIN hydrology. For each CALVIN rim inflow, the index basin with the maximum annual rim inflow correlation coefficient was chosen as the best mapping basin. For instance, with Method (1), the index basin i (i = 1, 2, …, 6) is identified by

$$I = \max_i \{r_{ij}\}$$

where i (i = 1, 2, …, m) represents index basin; j (j = 1, 2, …, n) represents CALVIN inflow; and r_{ij} represents the annual flow correlation coefficient between index basin i and CALVIN inflow j.

Method (5) identifies the index basins for the wet season and the dry season, respectively, for each CALVIN inflow, based on the index basin that has the least SSE of the monthly percentage distribution of annual streamflow (based on water year) with the CALVIN inflow monthly percentage distribution. To partition a water year into a wet season and a dry season facilitates finding the best fit for snowmelt- versus rainfall-driven runoff regimes. For instance, the most appropriate index basin for CALVIN inflow j in the wet season can be identified by:

$$I = \min_i \sum_{k \in Wet} \left(P_{ik} - P_{jk}\right)^2$$

where i (i = 1, 2, . . . , m) represents index basins, j (j = 1, 2, . . . , n) represents CALVIN rim inflow locations, and P_{ik} represents the k^{th} month percentage of annual streamflow of index basin i.

Method (6) compares the monthly percentage distribution of annual streamflow of index basins with CALVIN inflows in the wet season and the dry season and identifies a 1-month lag or shift in the distribution for an index basin in a few cases when that produces the best matching pattern. Figure 3 compares the monthly percentage distribution of annual streamflow of the six index basins with six CALVIN inflows: Cottonwood Creek, LV-Haiwee, Upper Owens, French Dry Creek, San Joaquin River, and Merced River. For instance, it was found through comparison that the monthly distribution of the Smith River is most similar to that of Cottonwood Creek, and LV-Haiwee fits with Kings River very well after the LV-Haiwee is shifted to the left by 1-month (LV-Haiwee has already been shifted in Figure 3).

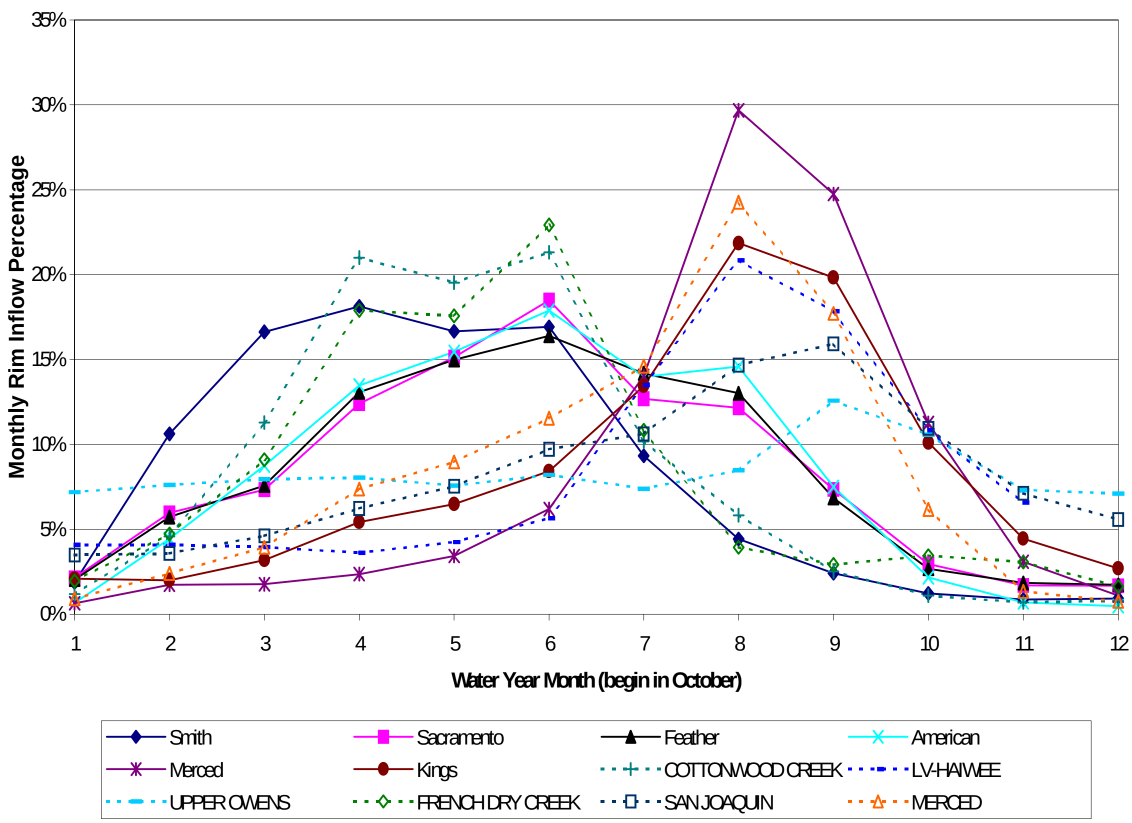

Fig. 3 Visual comparison of rim inflow percentage

Rim Inflow Calibration

For each scenario, the relative flow changes of each perturbed CALVIN rim inflow should be close to the relative changes of its index basins (Table 2). Numerous calibration and re-calculation iterations were carried out to find the "best" mapping matrix. To calibrate perturbed CALVIN rim inflows against those at index basins, first Method (1) was employed and problematic mappings were identified by comparing the changes against those at index basins. Second, new index basins for these problematic CALVIN inflows were identified with Method (5), and again, the remaining problematic mappings were determined. Finally, the remaining problematic CALVIN rim inflows were dealt with by Method (6), usually involving several trial and error processes. For the 37 CALVIN rim inflows, 18 are mapped with Method (5), 12 with Method (6), and 7 with Method (1). Numerous trial and error processes showed that different CALVIN rim inflows have different hydrologic characteristics and need different methods to relate them to the index basins. This combination of the three methods is the “best “ approach that we explored for mapping climate-induced flow changes of the six index basins to the 37 CALVIN rim inflows. Table 3 shows index basins for each CALVIN rim inflow.

Table 3. Wet and dry season index basins for each CALVIN rim inflow.

CALVIN rim inflow	Wet season index basin	Dry season index basin	CALVIN rim inflow	Wet season index basin	Dry season index basin
1. Trinity River	Sacramento	Sacramento	20. Greenhorn Creek and Bear River	American	American
2. Clear Creek	Smith	Smith	21. Kelly Ridge	Smith	Smith
3. Sacramento River	Sacramento	Sacramento	22. Stanislaus River	Feather	Kings
4. Stony Creek	Smith	Smith	23. San Joaquin River	Feather	Kings
5. Cottonwood Creek	Smith	Smith	24. Merced River	Feather	Kings
6. Lewiston Lake Inflow	Feather	American	25. Fresno River	Smith	Smith
7. Middle and South Forks Yuba River	American	American	26. Chowchilla River	Smith	Smith
8. Feather River	Feather	Sacramento	27. Clocal Inflow to New Don Pedro	Sacramento	American
9. North and Middle Forks American River	American	American	28. Tuolumne River	Merced	Merced
10. South Fork American River	Feather	Feather	29. Cherry and Elnor	Kings	Merced
11. Cache Creek	Smith	Smith	30. Santa Clara Valley Local	Smith	Smith
12. Putah Creek	Smith	Smith	31. Kern River	Kings	Kings
13. North Fork Yuba River	Feather	Feather	32. Kaweah River	Kings	Merced
14. Calaveras River	Smith	Smith	33. Tule River	Feather	Feather
15. Mokelumne River	Feather	Kings	34. Kings River	Kings	Kings
16. Cosumnes River	American	Feather	35. Lower Owens Valley - Haiwee	Kings	Kings
17. Deer Creek	Smith	Smith	36. Mono Basin	Merced	Kings
18. Dry Creek	Smith	Smith	37. Upper Owens	Kings	Sacramento
19. French Dry Creek	Smith	Smith			

Results of Perturbed Rim Inflows

Table 4 shows the total quantities and changes for the 37 CALVIN rim inflow basins. A wide range of projected changes in rim inflows is given. For instance, the total annual rim inflows could be 76.5% more than historical under a warm wet GCM climate scenario (HADCM2 2080-2099), and 25.5% less under a cool dry climate scenario (PCM 2080-2099). Except for the three PCM scenarios, there is an increase in inflow in the wet season. In all but the HADCM2 scenarios, there is a decrease in inflow in the dry season. Even in the three wet and warm HADCM2 scenarios, inflow increases in winter are much higher than in summer, resulting in an overall shift in annual runoff from the dry to the wet season seen in all scenarios except PCM 2010-2039.

Table 4. Overall rim inflow quantities and changes.

Climate scenario	Annual		October-March		April-September	
	Quantity (maf)	Change (%)	Quantity (maf)	Change (%)	Quantity (maf)	Change (%)
1. 1.5 T 0% P	28.6	1.1	16.4	15.6	12.2	-13.4
2. 1.5 T 9% P	32.4	14.6	18.7	31.7	13.7	-2.7
3. 3.0 T 0% P	28.5	0.9	18.2	28.0	10.3	-26.5
4. 3.0 T 18% P	36.2	28.1	23.3	64.4	12.8	-8.7
5. 5.0 T 0% P	27.9	-1.1	19.5	37.1	8.5	-39.7
6. 5.0 T 30% P	40.6	43.7	28.9	103.8	11.7	-17.0
7. HADCM22010-2039	38.5	36.4	22.0	54.9	16.5	17.6
8. HADCM22050-2079	41.3	46.4	25.8	82.0	15.5	10.4
9. HADCM2 2080-2099	49.8	76.5	33.3	134.3	16.6	18.1
10. PCM 2010-2039	26.5	-6.2	13.2	-6.7	13.2	-5.7
11. PCM 2050-2079	24.4	-13.6	13.7	-3.8	10.7	-23.5
12. PCM 2080-2099	21.1	-25.5	12.2	-14.2	8.9	-36.9
Historical	28.2	0.0	14.2	0.0	14.0	0.0

The monthly mean overall rim inflows for the 12 climate scenarios and historical data are plotted in Figure 4. The results show that these climate changes would significantly shift the peak runoff of catchments where the annual hydrograph is currently dominated by spring snowmelt. Much more runoff would occur in winter and less in spring and summer.

Table 5 (a-c) shows regional analyses for rim inflows in five CALVIN regions (Figure 2). Northern regions 1 and 2 account for 68% of annual rim inflows; southern regions 4 and 5 account for only a small portion of the annual rim inflows. With the warm and wet HADCM2 2080-2099 scenario, rim inflows in the south increase with higher percentages than in the north. With the cool and dry PCM 2080-2099 scenario, rim inflows decrease in all regions. In the wet season, rim inflows increase in all regions in all scenarios except the PCM scenarios. Rim inflows in the south increase at higher percentages than in the north for all except the PCM scenarios. In the dry season, rim inflows decrease for all regions for all scenarios except HADCM2 2080-2099, where only regions 1 and 2 experience inflow reduction. For most cases, rim inflows in the north decrease more seriously than in the south during dry season. These regional conclusions should be tempered by understanding that mapping inflows to index basins tended to be poorer further south, where there were fewer index basins.

Table 5a. Annual rim inflow (%) regional analysis.

Region	Historical annual (taf)[1]	Climate change scenario				
		3.0 T 0% P	5.0 T 0% P	5.0 T 30% P	HADCM2 2080-2099	PCM 2080-2099
1	8002	0.6	1.1	43.8	56.3	-22.1
2	11120	1.3	-0.3	46.1	75.1	-25.5
3	5741	1.3	-5.5	38.9	91.4	-27.6
4	2826	0.0	-1.3	43.8	104.9	-29.3
5	555	-2.8	-0.2	45.4	96.3	-31.5
Statewide	28244	0.9	-1.1	43.7	76.5	-25.5

Note 1: thousand acre-feet.

Table 5b. Wet season rim inflow (%) regional analysis.

Region	Historical October-March (taf)	Climate change scenario				
		3.0 T 0% P	5.0 T 0% P	5.0 T 30% P	HADCM2 2080-2099	PCM 2080-2099
1	4872	20.3	26.0	84.0	101.9	-15.4
2	6323	28.1	32.3	99.4	139.9	-15.5
3	2097	38.3	52.8	127.7	158.3	-9.5
4	751	46.8	98.0	189.7	217.3	-7.5
5	156	35.6	76.7	168.4	195.4	-18.0
Statewide	14199	28.0	37.1	103.8	134.3	-14.2

Table 5c. Dry season rim inflow (%) regional analysis.

Region	Historical April-September (taf)	Climate change scenario				
		3.0 T 0% P	5.0 T 0% P	5.0 T 30% P	HADCM2 2080-2099	PCM 2080-2099
1	3130	-30.1	-37.7	-18.8	-14.7	-32.7
2	4797	-34.1	-43.2	-24.2	-10.3	-38.7
3	3643	-20.0	-39.1	-12.2	52.8	-38.0
4	2076	-17.0	-37.2	-8.9	64.2	-37.1
5	399	-17.8	-30.2	-2.5	57.6	-36.7
Statewide	14045	-26.5	-39.7	-17.0	18.1	-36.9

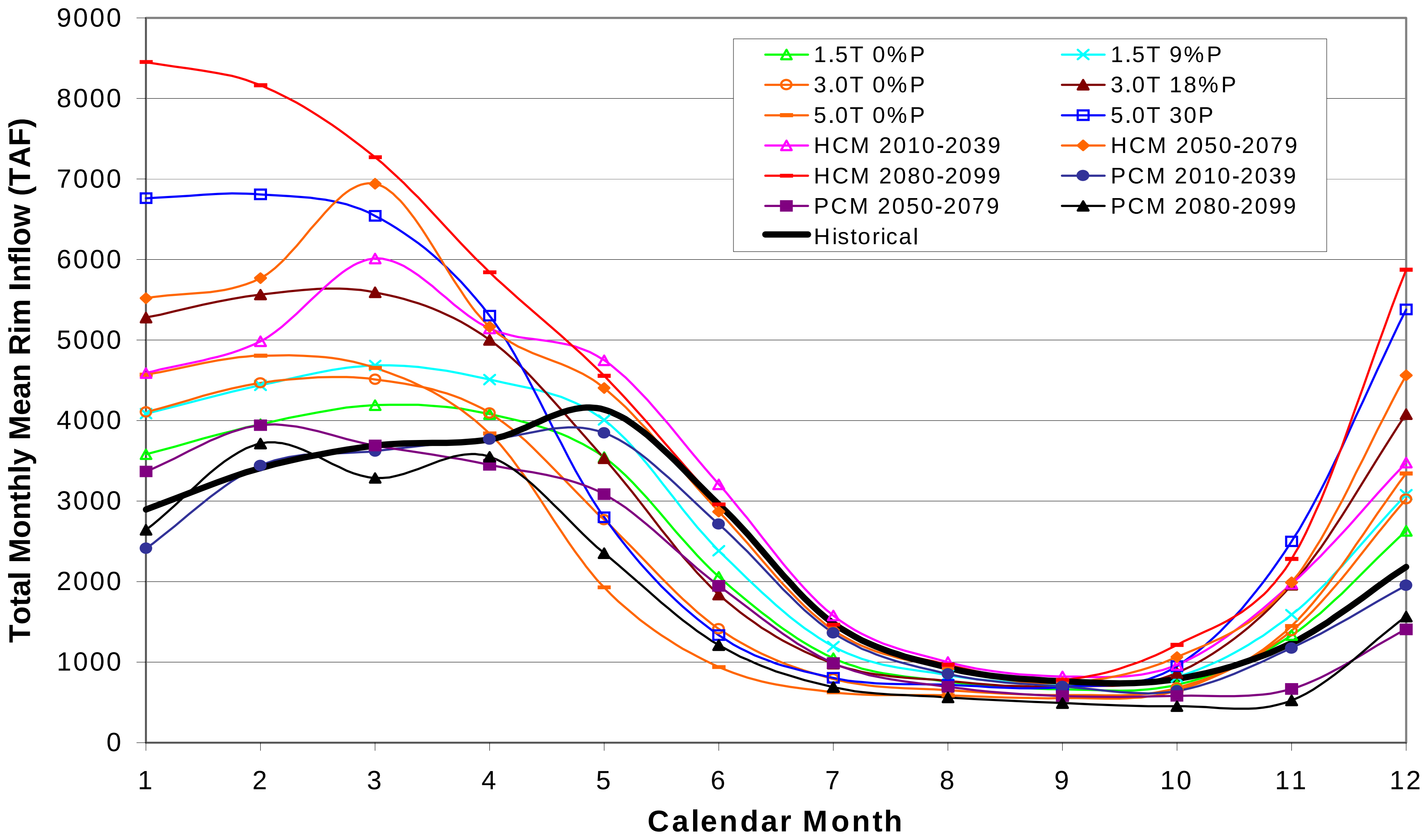

Fig. 4-a 72-year monthly mean rim inflows for the 12 climate scenarios and historical data

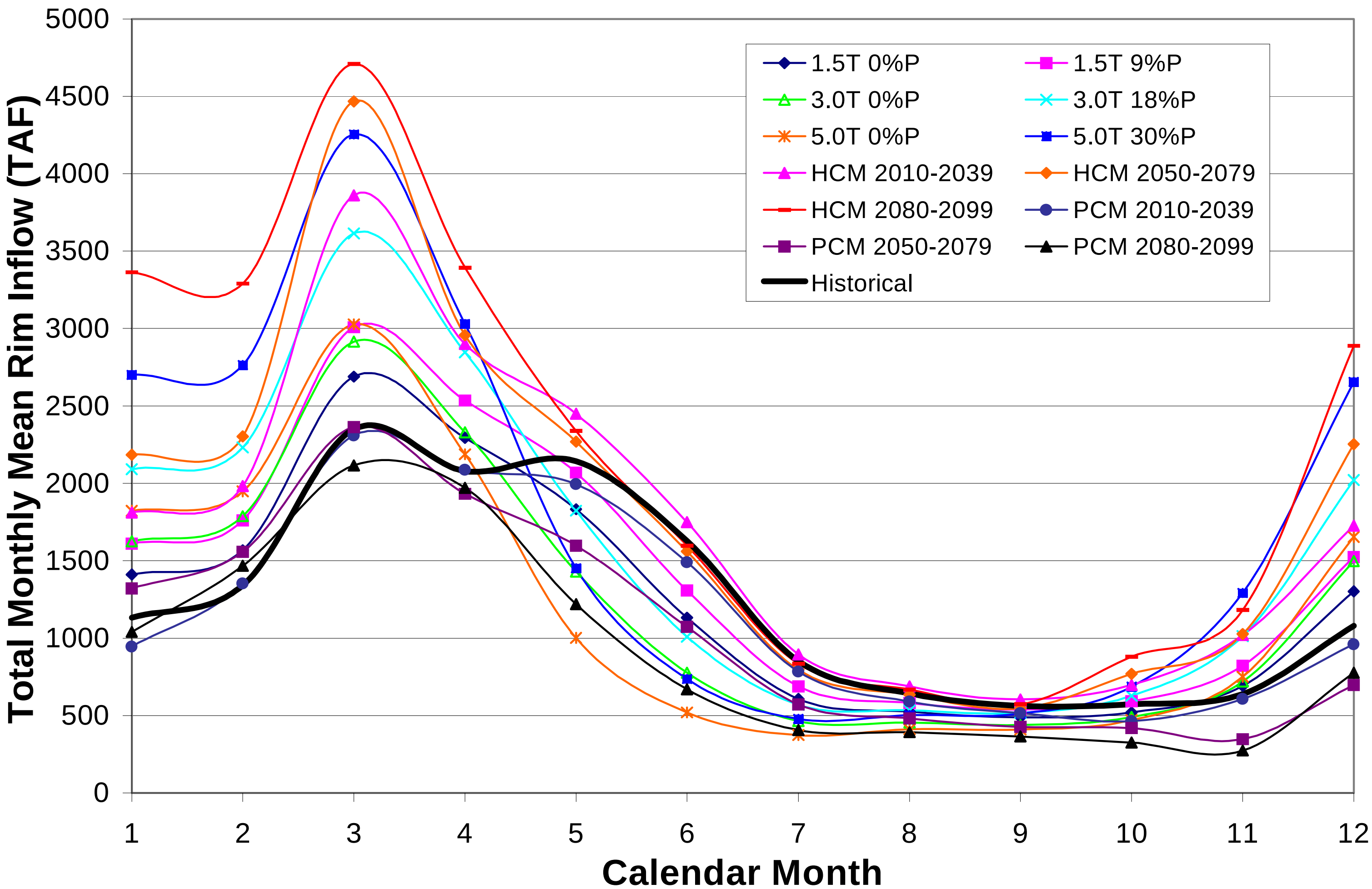

Fig. 4-b 14 drought years' monthly mean rim inflows for the 12 climate scenarios and historical data

Considering these results, Figure 4 shows that the monthly average of 72 year perturbed rim inflows for the 12 climate change scenarios gives an important and reasonable range of hydrological responses to climate change in California. As statistical interpolations and extrapolations of the changes projected for the six index basins, the perturbed CALVIN rim inflows present a reasonable set of projections under different climate change scenarios. However, for a few CALVIN rim inflows, especially those in the southern parts of the state, the annual and seasonal mean changes are not very close to those of index basins under the same climate change scenarios. For instance, San Joaquin River has a -10.3% annual inflow reduction under the 5.0 T 0% P uniform incremental scenario, while the corresponding changes of its two index basins, the Feather River and the Kings River, are 3.1% and 4.8%, respectively. The San Joaquin River annual rim inflow is 1.681 maf, accounting for 6% of the total amount of annual rim inflows. From Figure 3, it is apparent no index basin exists with a monthly distribution pattern similar to that of the San Joaquin. The result for the San Joaquin River, then, is not very good. The same problem occurs with the Upper Owens located on the east side of the southern Sierras. It has an annual inflow of 0.143 maf, accounting for only 0.5% of the annual total rim inflows. Flow quantities of these problematic rim inflow locations account for a small portion (less than 15%) of the total. However, they indicate that simulations of more index basins south of the delta, along the coast and in the Central Valley floor would be useful.

Flow quantities and percentage changes for all 37 rim inflows appear in Table A at the end of this attachment.

RESERVOIR EVAPORATION

The CALVIN model has 47 surface reservoirs for which evaporation is calculated. Historically, over the 72 year hydrology history used in CALVIN, 1.6 maf/yr of water is lost from these reservoirs as net evaporation under current reservoir operations, which represents about 4% of all inflows. Changes in evaporation rate and in total evaporation, assuming the same operations, for each reservoir were estimated for each climate scenario.

Method Description

The net evaporation rate at reservoir *i* is

$$NetE_i = E_i - P_i$$

where E_i is monthly evaporation rate and P_i is monthly precipitation rate. A two-variable linear regression equation can be employed to represent the historical empirical relationship between monthly average net evaporation rate in feet and monthly average air temperature and precipitation at each surface reservoir.

$$NetE_i = a_i T + b_i P + c_i$$

where T is monthly mean air temperature in degrees F, P is the monthly mean precipitation in feet, and a_i and b_i are regression coefficients. The CALVIN monthly average net evaporation rate (in feet) at each reservoir for the period from 1961 to 1990 was regressed against the NWS average monthly air temperature and precipitation data for the same period at the nearest weather station to each CALVIN reservoir (NWS, January 2002). At nearly all reservoirs, the regression analysis of the 12 months of average conditions produced very good fits.

The reservoir net evaporation rate increase for scenario j is obtained from the following empirical equation:

$$\Delta NetE_{ijm} = a_i \cdot \Delta T_{jm} + b_i \cdot \left(1 + \Delta P_{jm}\right)\overline{P_{im}}$$

where $\Delta NetE_{ijm}$ is the average incremental net evaporation rate (feet) in month m, under climate scenario j, at reservoir i; ΔT_{jm} is the average temperature increase (ºF) in month m under climate scenario j; ΔP_{jm} is the average precipitation increase ratio under climate scenario j for month m; $\overline{P_{im}}$ is the historical m^{th} month average precipitation in feet at reservoir i; and a_i and b_i are coefficients the same as in the above regression equation. In the incremental climate scenarios (1 to 6), the temperature and precipitation shift is uniform in each month. In contrast, the GCM scenarios have average temperature and precipitation shifts that vary by month.

The monthly incremental net evaporation rate at each reservoir is then added to the historical monthly net evaporation rate time series for that reservoir. Next, the monthly net evaporation quantity, based on current storage operations, is obtained from the perturbed net evaporation rate using simulated historical reservoir monthly surface area.

$$NetEQ_{ijym} = NetE_{ijm} \times A_{iym}$$

where $NetEQ_{ijym}$ is net evaporation quantity (net evaporation for short) at reservoir i, under scenario j, in the m^{th} month of the y^{th} year; and A_{iym} is the surface area of the i^{th} reservoir in the m^{th} month of the y^{th} year.

Results of Net Evaporation

Results show net evaporation increases between 3.6% and 41.3%. Most of the regression equations have a high significance level, with net evaporation rates being more sensitive to temperature than precipitation.

The perturbed CALVIN total reservoir evaporation can provide a reasonable estimate for changes in net evaporation losses under different climate scenario assumptions. However, there are some limitations to temperature- and precipitation-driven net evaporation change formulation, because evaporation changes tend to be physically driven by solar radiation changes (for which there is currently no accurate climate scenario information), rather than by ambient air temperature changes. Spatially, solar radiation is a function of cloud cover, which is a weak point of GCMs. Temperature changes are used as a surrogate and easy-to-obtain factor in this study.

Table 6 shows average annual and seasonal surface reservoir evaporation quantities and changes over the 72 year hydrologic time series. The data indicate that reservoir evaporation increases for all 12 climate scenarios as a result of increased temperature. Relative increases are greater in the wet season, but absolute volume increases tend to greater in the dry season. For all GCM scenarios, evaporation will increase more over time.

Table 6. Surface reservoir evaporation quantities and changes.

Climate scenario	Annual Quantity (maf)	Annual Change (%)	October-March Quantity (maf)	October-March Change (%)	April-September Quantity (maf)	April-September Change (%)
1. 1.5 T 0% P	1.83	12.4	0.46	27.0	1.36	8.1
2. 1.5 T 9% P	1.81	11.6	0.45	24.3	1.36	7.9
3. 3.0 T 0% P	2.03	24.8	0.56	54.0	1.46	16.3
4. 3.0 T 18% P	2.00	23.2	0.54	48.5	1.46	15.8
5. 5.0 T 0% P	2.30	41.3	0.70	90.0	1.60	27.1
6. 5.0 T 30% P	2.25	38.6	0.66	80.9	1.59	26.3
7. HADCM2 2010-2039	1.77	9.0	0.43	16.8	1.34	6.7
8. HADCM2 2050-2079	1.90	16.9	0.49	33.3	1.41	12.1
9. HADCM2 2080-2099	1.98	21.7	0.52	40.7	1.46	16.2
10. PCM 2010-2039	1.68	3.6	0.40	8.0	1.29	2.3
11. PCM 2050-2079	1.84	13.5	0.48	30.8	1.37	8.5
12. PCM 2080-2099	1.98	21.6	0.55	49.9	1.43	13.4
Historical	1.62	0.0	0.37	0.0	1.26	0.0

Table B at the end of this appendix summaries evaporation results for each of the 47 CALVIN surface reservoirs.

GROUNDWATER AND LOCAL SURFACE ACCRETIONS

The CALVIN model has 28 groundwater inflows and 35 local surface water accretions. For the seven groundwater basins located outside the Central Valley, there are not enough data to model the relationship between precipitation and deep percolation recharge from rainfall. (For more details on CALVIN hydrology, see the technical appendices of Jenkins et al., 2001.) Therefore, only the 21 groundwater basins and 28 local surface accretions in the Central Valley have been perturbed for climate change. These 21 groundwater basins and 28 local surface accretions account for 6.8 and 4.4 maf/yr, respectively, of total inflows into California's intertied water system, representing about 17% and 11%, respectively, of all inflows. Only a portion of the 6.8 maf/yr of natural groundwater inflow is attributable to direct deep percolation of rainfall.

To estimate climate change effects on groundwater inflows and local surface water accretions, we partition precipitation changes into local runoff and deep percolation portions for each groundwater basin. These changes are then added to appropriate historical local accretion and groundwater inflow time series. We do not consider the unsaturated layer water balance or any changes in stream-aquifer exchanges from the CALVIN base case condition.

Estimating Deep Percolation Changes

A cubic regression equation is employed to represent the nonlinear relationship between monthly deep percolation (in taf) and precipitation (in taf) for each groundwater basin from Central Valley Ground and Surface Water Model (CVGSM) simulated data over the 1922-1990 period (USBR, 1997) as shown below. It is assumed that no constant term is needed in the equation because deep percolation cannot happen without precipitation.

$$DP_i = a_i P_i^3 + b_i P_i^2 + c_i P_i$$

where DP_i is deep percolation at groundwater basin i in a month; P_i is monthly precipitation over groundwater basin i; and a_i, b_i, and c_i are regression coefficients. This relationship is demonstrated in Figure 5 for groundwater basin 11.

The increased deep percolation can be represented with the differential form of the previous equation.

$$\Delta DP_i = \left(3a_i P_i^2 + 2b_i P_i + c_i\right) \times \left(\Delta P_i \times P_i\right)$$

where ΔP_i is average precipitation change ratio for the climate change scenarios.

Cubic regression equation was chosen because this form fits the empirical data for most groundwater basins very well. In addition, for most cases there is a peak plateau on the curve that can represent infiltration capacity.

For the six uniform incremental scenarios, the specified statewide annual average precipitation change was applied in each month. For the six GCM scenarios, temporally (monthly) and spatially distributed average precipitation change ratios were available for all 28 of the groundwater basins, based on the 1963-1993 climate simulation period. Table 7 shows the average monthly precipitation change percentage for the 28 groundwater basins under the six GCM scenarios. Table 8 shows the parameters and multiple correlation coefficients for the deep percolation regression equation for each of the 21 Central Valley groundwater basins. The high correlation coefficients indicate reasonable relationships between precipitation and deep percolation. The seven other basins were not modeled because no data are available to estimate the deep percolation equations. These groundwater basins are outside the Central Valley.

Table 7. Average percent monthly precipitation change ratios for GCM scenarios.

Climate scenario	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
7. HADCM2 2010-2039	26	27	24	23	20	2	1	4	6	15	11	-5
8. HADCM2 2050-2079	33	34	34	30	32	17	18	24	22	29	37	25
9. HADCM2 2080-2099	62	62	57	55	59	49	40	43	38	45	56	64
10. PCM 2010-2039	-16	3	-25	-1	24	5	18	-16	-13	4	14	-18
11. PCM 2050-2079	-12	-13	-15	-14	-12	-17	-22	-22	-20	-19	-32	-27
12. PCM 2080-2099	-26	-27	-28	-27	-29	-30	-30	-31	-27	-21	-30	-16

Table 8. Parameters of deep percolation equation for each groundwater basin.

Ground-water basin	a	b	c	Multiple correlation coefficient	Ground-water basin	a	b	c	Multiple correlation coefficient
1	-2.89E-06	0.00140	0.03792	0.89	12	-5.6E-06	0.00126	0.05344	0.90
2	-1.753E-06	0.00150	-0.02612	0.92	13	-7.8E-07	0.00048	0.05044	0.86
3	-2.27E-06	0.00148	-0.05748	0.91	14	-3.9E-06	0.00385	-0.06876	0.96
4	-2.986E-06	0.00113	0.00558	0.93	15	-8.7E-07	0.00071	0.00933	0.89
5	-8.47E-07	0.00090	0.00624	0.93	16	-2.2E-06	0.00058	0.04886	0.89
6	-6.285E-07	0.00046	0.03964	0.89	17	-1.2E-07	0.00009	0.04782	0.86
7	-1.874E-07	0.00060	0.04097	0.86	18	-3.5E-07	0.00057	0.02269	0.92
8	-1.017E-07	0.00009	0.03983	0.86	19	-3.4E-06	0.00228	-0.02920	0.93
9	-1.427E-06	0.00116	-0.00505	0.88	20	-6.8E-06	0.00225	0.03627	0.89
10	-2.388E-06	0.00110	0.01743	0.89	21	-4.4E-06	0.00254	-0.01272	0.91
11	-1.952E-05	0.00730	-0.09043	0.96					

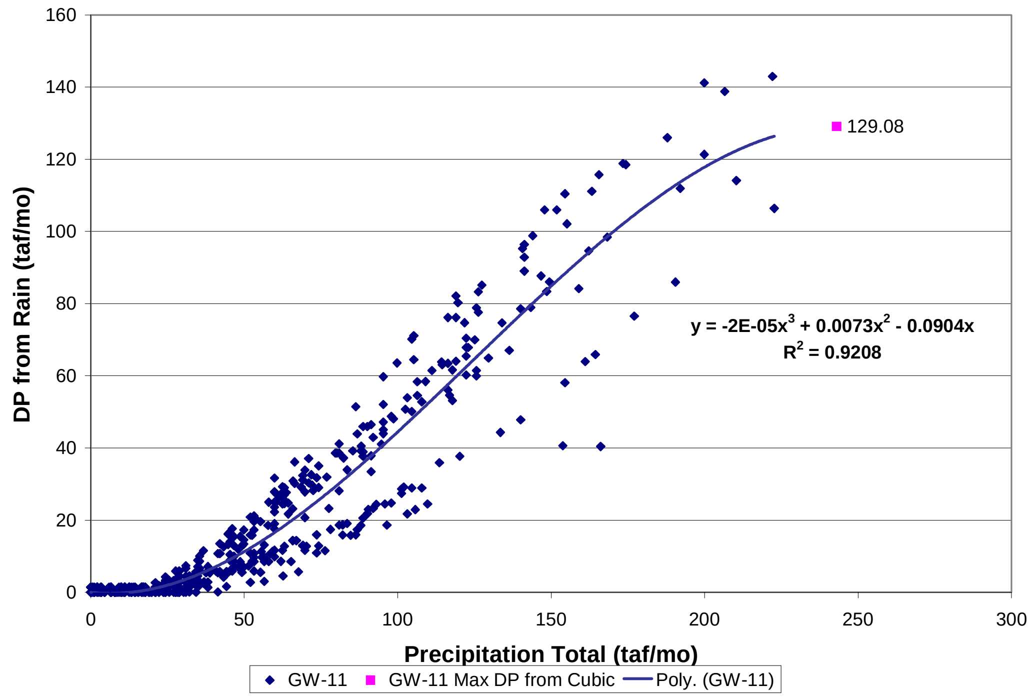

Fig. 5 Cubic regression curve for deep percolation in groundwater basin 11

Groundwater Inflow

Natural groundwater inflows or recharge (excluding recharge from operational deliveries to agricultural and urban demand areas), in the Central Valley from CVGSM can be represented as

$$I_i = DP_i + SA_i + BF_i + SS_i + LS_i + AR_i$$

where:

DP_i = percolation of rain in basin i
SA_i = gain from streams in basin i
BF_i = gain from boundary flows (from outside the CVGSM modeled area) in basin i
SS_i = gain in basin i from subsurface flows across basin boundaries
LS_i = seepage from lake beds and bedrock in basin i
AR_i = seepage from canals and artificial recharge in basin i.

If we assume that other components of groundwater inflow are unchanged (a simplifying assumption), the change in groundwater inflow is equivalent to the change in deep percolation from changes in rainfall over the basin; that is,

$$I_{i,perturbed} = I_i + \Delta DP_i$$

where $I_{i,perturbed}$ is perturbed groundwater inflows in basin i.

Local Surface Water Accretion

Local surface water accretion can be represented as

$$LA_i = R_i + AG_i \qquad (AG_i = -SA_i)$$

where LA_i is net local surface water accretion, R_i is direct runoff, and AG_i is gain from aquifer. Increased local accretion over a groundwater basin, then, equals increased precipitation minus increased deep percolation, assuming a negligible change in evaporation from changed precipitation, which is probably not a major problem in most wet months. As a result, the perturbed local surface water accretion equals

$$LA_{i,perturbed} = LA_i + (\Delta P_i \times P_i - \Delta DP_i)$$

To connect groundwater inflow with local accretion, each groundwater basin is associated with a local accretion depletion area that coincides with the groundwater basin.

Results of Groundwater Inflows and local surface water accretions

Tables 9 and 10 show the annual and seasonal changes of groundwater inflows and local surface water accretions. In most cases, local surface water accretions and groundwater flows in the wet season greatly exceed those in the dry season. For all three future GCM periods, local surface water accretions and groundwater inflows increase with HADCM2 scenarios and decrease with PCM scenarios. Over time, local surface water accretions and groundwater inflows increase with HADCM2 scenarios, but decrease with PCM scenarios.

Table 9. Groundwater inflow quantities and changes.

Climate scenario	Annual		October-March		April-September	
	Quantity (maf)	Change (%)	Quantity (maf)	Change (%)	Quantity (maf)	Change (%)
1. 1.5 T 0% P	6.78	0.0	3.60	0.0	3.18	0.0
2. 1.5 T 9% P	7.01	3.4	3.80	5.5	3.21	1.0
3. 3.0 T 0% P	6.78	0.0	3.60	0.0	3.18	0.0
4. 3.0 T 18% P	7.24	6.8	4.00	11.1	3.24	1.9
5. 5.0 T 0% P	6.78	0.0	3.60	0.0	3.18	0.0
6. 5.0 T 30% P	7.55	11.3	4.27	18.5	3.28	3.2
7. HADCM2 2010-2039	7.51	10.7	4.17	15.8	3.33	5.0
8. HADCM2 2050-2079	7.68	13.3	4.42	22.7	3.26	2.5
9. HADCM2 2080-2099	8.37	23.5	5.08	41.1	3.29	3.5
10. PCM 2010-2039	6.61	-2.5	3.42	-5.0	3.19	0.3
11. PCM 2050-2079	6.44	-5.0	3.33	-7.6	3.11	-2.0
12. PCM 2080-2099	6.21	-8.5	3.08	-14.5	3.12	-1.7
Historical	6.78	0.0	3.60	0.0	3.18	0.0

Table 10. Local surface water accretion quantities and changes.

Climate scenario	Annual		October-March		April-September	
	Quantity (maf)	Change (%)	Quantity (maf)	Change (%)	Quantity (maf)	Change (%)
1. 1.5 T 0% P	4.42	0.0	3.54	0.0	0.88	0.0
2. 1.5 T 9% P	5.45	23.3	4.39	23.9	1.06	21.1
3. 3.0 T 0% P	4.42	0.0	3.54	0.0	0.88	0.0
4. 3.0 T 18% P	6.48	46.6	5.23	47.7	1.25	42.1
5. 5.0 T 0% P	4.42	0.0	3.54	0.0	0.88	0.0
6. 5.0 T 30% P	7.85	77.7	6.36	79.5	1.49	70.2
7. HADCM2 2010-2039	7.94	79.7	6.04	70.4	1.91	117.4
8. HADCM2 2050-2079	8.55	93.4	7.04	98.7	1.51	72.0
9. HADCM2 2080-2099	11.41	158.1	9.72	174.3	1.69	92.8
10. PCM 2010-2039	4.26	-3.5	3.23	-8.8	1.03	18.0
11. PCM 2050-2079	3.89	-12.0	3.08	-12.9	0.81	-8.2
12. PCM 2080-2099	3.17	-28.2	2.36	-33.2	0.81	-7.8
Historical	4.42	0.0	3.54	0.0	0.88	0.0

Results show that local surface water accretions are more sensitive to precipitation changes than groundwater inflows. This is mainly because the infiltration capacity effect in the regression analysis sets a limit for deep percolation, and therefore, most increased precipitation contributes to direct local runoff. Also, deep percolation of rainfall accounts for about 1.7 maf/yr of the total 6.8 maf/yr of average groundwater inflow in the Central Valley. Under the historical climate, this volume represents only about 12% of precipitation falling over groundwater basins in the Central Valley.

Tables C at the end of this attachment summarize inflows and changes for each groundwater basin in the CALVIN model.

TOTAL WATER QUANTITY AND CHANGES

Total water quantity available in a region is the sum of rim inflows, local net surface water accretions, and groundwater inflows, minus evaporation losses. Because rim inflows account for a large portion of overall water quantity in California, the changes in total water quantity are similar to those of rim inflows. However, groundwater and local accretion contribute significantly to overall water quantity, which make the overall changes slightly different from rim inflow changes. These differences are discussed in the next section.

In general, statewide results (see Tables 11 and 12) show that these climate changes would result in significant shifts in the peak season of water availability. Snowmelt comes much earlier than it has historically. Relatively more of the annual runoff would occur in the wet season and less in the dry season; wet seasons will become wetter and dry seasons will become drier. The three wet and warm HADCM2 scenarios indicate that future decades will experience much more water, and water availability will increase over time. The dry and cool PCM scenarios indicate that less water will be available and that conditions will worsen as time goes on. For drought years, overall water quantities show significant decreases for all scenarios except HADCM2 2080-2099. Compared with historical averages, drought years (1928-1934, 1976-1977, and 1987-1992) are expected to experience serious water decreases, although HADCM2 2080-2099 results show only moderate reductions..
Regional analyses (Table 13, a-c) indicate that southern regions are more sensitive to climate changes under HADCM2 scenarios because the South could see a higher precipitation increase than the North. Under HADCM2 2080-2099 scenario, southern regions (regions 3 and 4) have increased water availability even in the dry season. Under PCM scenarios, water availability decreases for all seasons in all CALVIN regions. No significant spatial trend was found for PCM scenarios.

Table 11. Overall water quantities and changes.

Climate scenario	Annual		October-March		April-September	
	Quantity (maf)	Change (%)	Quantity (maf)	Change (%)	Quantity (maf)	Change (%)
1. 1.5 T 0% P	37.9	0.3	23.1	10.1	14.9	-11.8
2. 1.5 T 9% P	43.0	13.7	26.4	26.0	16.6	-1.5
3. 3.0 T 0% P	37.7	-0.4	24.8	18.0	12.9	-23.4
4. 3.0 T 18% P	47.9	26.6	32.0	52.7	15.9	-5.9
5. 5.0 T 0% P	36.8	-2.6	25.9	23.6	10.9	-35.1
6. 5.0 T 30% P	53.7	42.1	38.9	85.5	14.8	-11.9
7. HADCM2 2010-2039	52.2	38.0	31.8	51.5	20.4	21.2
8. HADCM2 2050-2079	55.7	47.2	36.8	75.5	18.9	12.0
9. HADCM2 2080-2099	67.6	78.9	47.5	126.6	20.1	19.3
10. PCM 2010-2039	35.7	-5.6	19.5	-7.0	16.2	-3.9
11. PCM 2050-2079	32.9	-13.0	19.6	-6.6	13.3	-21.0
12. PCM 2080-2099	28.5	-24.8	17.1	-18.6	11.4	-32.5
Historical (1921-1993)	37.8	0.0	21.0	0.0	16.8	0.0

Table 12. Drought year overall water quantities and changes.

Climate scenario	Annual		October-March		April-September	
	Quantity (maf)	Change (%)	Quantity (maf)	Change (%)	Quantity (maf)	Change (%)
1. 1.5 T 0% P	23.6	-0.6	12.3	8.7	11.3	-9.0
2. 1.5 T 9% P	26.5	11.9	14.2	25.5	12.3	-0.5
3. 3.0 T 0% P	23.3	-1.8	13.1	15.5	10.2	-17.7
4. 3.0 T 18% P	29.2	23.2	17.2	51.7	12.0	-2.9
5. 5.0 T 0% P	22.7	-4.3	13.6	20.1	9.1	-26.6
6. 5.0 T 30% P	32.4	36.8	20.8	84.0	11.6	-6.3
7. HADCM2 2010-2039	32.4	36.9	17.3	52.8	15.1	22.3
8. HADCM2 2050-2079	34.3	44.9	20.1	78.0	14.2	14.6
9. HADCM2 2080-2099	40.9	72.5	25.9	128.9	15.0	21.1
10. PCM 2010-2039	22.6	-4.5	10.5	-7.4	12.2	-1.8
11. PCM 2050-2079	20.8	-12.1	10.3	-8.7	10.5	-15.3
12. PCM 2080-2099	18.2	-23.3	9.0	-20.6	9.2	-25.8
Historical (drought years)	23.7	0.0	11.3	0.0	12.4	0.0

Table 13a. Regional analysis of overall annual water quantities and changes (%).

Region	Historical annual (taf)	Climate change scenario				
		3.0 T 0% P	5.0 T 0% P	5.0 T 30% P	HADCM2 2080-2099	PCM 2080-2099
1	10576	0.1	0.3	42.0	57.7	-21.9
2	14002	0.5	-1.1	45.6	77.2	-25.7
3	7078	-0.2	-6.5	38.6	92.0	-26.9
4	6568	-0.1	-0.8	36.9	91.8	-18.1
5[a]	-406	53.6	83.2	14.5	-89.7	87.1
Statewide	37818	-0.4	-2.6	42.1	78.9	-24.8

a. Only rim inflows and surface reservoir evaporations are taken into account in region 5.

Table 13b. Regional analysis of overall wet season water quantities and changes (%).

Region	Historical October-March (taf)	Climate change scenario				
		3.0 T 0% P	5.0 T 0% P	5.0 T 30% P	HADCM2 2080-2099	PCM 2080-2099
1	6972	14.0	17.8	70.1	92.9	-17.9
2	8635	20.1	23.0	85.5	129.0	-19.7
3	2866	26.6	36.1	109.6	156.3	-16.3
4	2604	13.3	28.0	92.3	162.7	-13.6
5[b]	-100	45.5	48.6	-112.2	-230.2	121.9
Statewide	20977	18.0	23.6	85.5	126.6	-18.6

a. Only rim inflows and surface reservoir evaporations are taken into account in region 5.

Table 13c. Regional analysis of overall dry season water quantities and changes (%).

Region	Historical April-September (taf)	Climate change scenario				
		3.0 T 0% P	5.0 T 0% P	5.0 T 30% P	HADCM2 2080-2099	PCM 2080-2099
1	3603	-26.6	-33.6	-12.4	-10.4	-29.7
2	5367	-31.2	-39.8	-18.5	-6.1	-35.3
3	4212	-18.3	-35.5	-9.7	48.2	-34.1
4	3964	-9.0	-19.7	0.4	45.3	-21.1
5[a]	-306	56.3	94.5	55.8	-44.0	75.8
Statewide	16841	-23.4	-35.1	-11.9	19.3	-32.5

a. Only rim inflows and surface reservoir evaporations are taken into account in region 5.

Figure 6 (a-c) shows annual and seasonal exceedence probabilities of statewide total water quantities for CALVIN, based on the 72 year 1922-1993 historical hydrology. In the annual case, HADCM2 2080-2099 and PCM 2080-2099 form the upper and lower exceedence probability curves. The averaged annual overall water quantity could be as high as 156.2 maf under the HADCM2 2080-2099 scenario, and as low as 9.5 maf under the PCM 2080-2099 scenario. In the dry season, HADCM2 2010-2039 and uniform incremental 5.0T 0%P form the upper and lower curves with a range of annual quantities from 30.6 maf to 2.6 maf. HADCM2 2080-2099 and PCM 2080-2099 in the wet season, varying from 127.3 maf to 5.3 maf per year, defined the upper and lower exceedence probability.

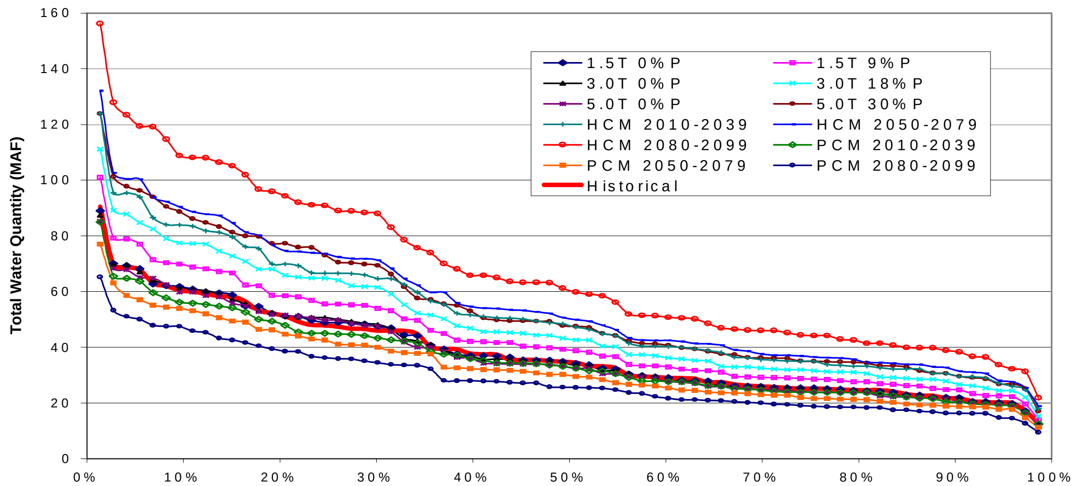

Fig. 6-a Annual exceedence probability

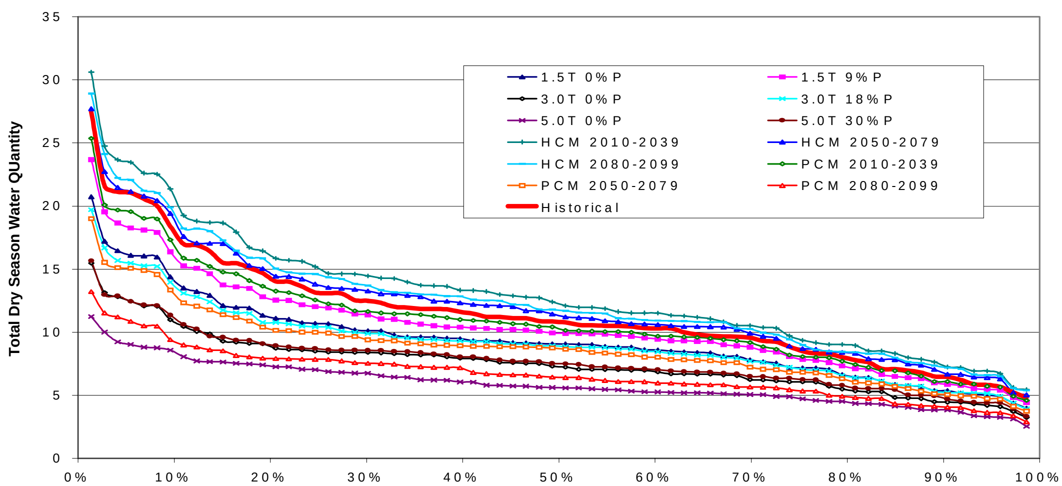

Fig. 6-b Dry season exceedence probability

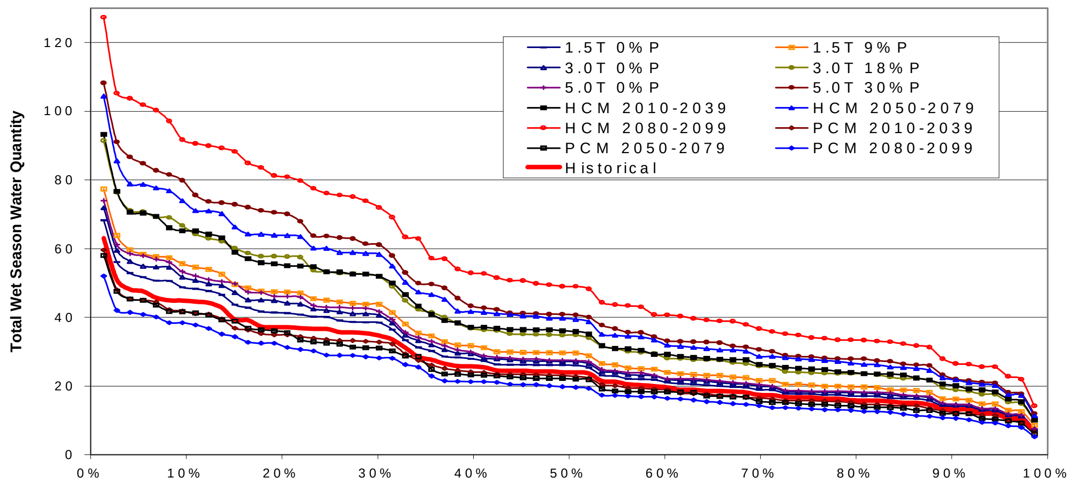

Fig. 6-c Wet season exceedence probability

ESTIMATED CHANGES IN WATER SUPPLY AVAILABILITY

Accumulated estimation of changes in water supply with climate change requires the use of operations models of facilities and operating policies. However, before this can be done (using the CALVIN model), it is possible to estimate changes in water available for water supply management from climate changes. To do this we assume (1) all changes in dry season inflows directly affect water deliveries (because water is most easily managed during the dry season); (2) increases in wet season surface inflows are lost because of low water demand and low surface storage flexibility resulting from flood control; and (3) changes in wet season groundwater inflows directly affect water supply availability because they directly affect groundwater storage. Because there is likely to be more wet season storage flexibility than is assumed here, the resulting estimates are likely to be more dire than more realistic results from operations modeling.

Table 14 shows the results of water availability analyses. On average, water availability decreases for all 12 climate scenarios except the three HADCM2 ones, in which water availability increases even in the dry season. For the three uniform precipitation and temperature increase scenarios (1.5T 9%P, 3.0T 18%P, and 5.0T 30%P), actual water availability decreases even though overall water quantities increase as shown in the last section. In drought years, water availability decreases significantly for all 12 scenarios. These conclusions are important to identify potential water supply problems. If the huge amount of increased inflow in the wet season cannot be stored and effectively managed, dry season water supply could decrease significantly even though overall annual water quantity increases. Effective management of wet season groundwater could moderate dry season water supply problems.

Table 14. Raw water availability estimates and changes (without operational adaptation, in maf).

Climate scenario	Average annual water availability		Drought year annual water availability	
	Volume maf	Change maf (%)	Volume maf	Change maf (%)
1. 1.5 T 0% P	35.7	-2.1 (-5.5)	22.5	-1.2 (-5.1)
2. 1.5 T 9% P	37.7	-0.1 (-0.4)	23.7	0.0 (0.0)
3. 3.0 T 0% P	33.7	-4.1 (-10.9)	21.3	-2.4 (-9.9)
4. 3.0 T 18% P	37.1	-0.8 (-2.0)	23.4	-0.2 (-1.0)
5. 5.0 T 0% P	31.6	-6.2 (-16.5)	20.1	-3.6 (-15.1)
6. 5.0 T 30% P	36.2	-1.6 (-4.3)	23.1	-0.6 (-2.5)
7. HADCM2 2010-2039	41.9	4.1 (10.8)	26.7	3.0 (12.8)
8. HADCM2 2050-2079	40.5	2.7 (7.2)	25.9	2.2 (9.4)
9. HADCM2 2080-2099	42.4	4.6 (12.1)	27.2	3.5 (14.7)
10. PCM 2010-2039	35.7	-2.1 (-5.6)	22.6	-1.1 (-4.5)
11. PCM 2050-2079	32.9	-4.9 (-13.0)	20.8	-2.9 (-12.1)
12. PCM 2080-2099	28.5	-9.4 (-24.8)	18.2	-5.5 (-23.3)
Historical	37.8	0.0 (0.0)	23.7	0.0 (0.0)

THE IMPORTANCE OF MORE COMPLETE HYDROLOGIC REPRESENTATION

Table 15 compares the changes of rim inflows with those of overall water availability under the 12 climate scenarios. Overall water availability decreases more significantly than rim inflows under temperature increase with no more precipitation scenarios, and increases less significantly than rim inflows under temperature increase with more precipitation scenarios partly because reservoir evaporations were accounted for in the overall water availability but also because the increase in rainfall is applied to both wet and dry seasons. Under all the GCM scenarios, overall water availability increases more significantly or decreases less significantly than rim inflows. Moreover, overall water availability shows a relatively moderate shift of water from dry season to wet season compared with the seasonal shift of rim inflows. Considering that most of the wet season groundwater inflows are stored for dry season consumption, as shown in column (8) of the table, the sum of dry season overall water availability plus wet season groundwater inflows decreases much less significantly than both rim inflows and overall water availability in the dry season under all the uniform incremental and PCM scenarios (when the dry season experiences serious water decreases). This further indicates that groundwater inflow and other components of hydrologic change help to dampen overall fluctuations in water availability.

Table 15. Comparison of water quantity with different hydrologic components (maf/yr)

	Annual		October-March			April-September		
	Rim inflow	Overall	Rim inflow	Overall	Overall – groundwater inflows	Rim inflow	Overall	Overall + wet season groundwater inflows
Climate scenario	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
1. 1.5 T 0% P	28.6	35.8	16.4	23.1	19.5	12.2	14.9	18.5
2. 1.5 T 9% P	32.4	37.8	18.7	26.4	22.6	13.7	16.6	20.4
3. 3.0 T 0% P	28.5	33.9	18.2	24.8	21.2	10.3	12.9	16.5
4. 3.0 T 18% P	36.2	37.2	23.3	32.0	28.0	12.8	15.9	19.9
5. 5.0 T 0% P	27.9	31.9	19.5	25.9	22.3	8.5	10.9	14.5
6. 5.0 T 30% P	40.6	36.5	28.9	38.9	34.6	11.7	14.8	19.1
7. HADCM2 2010-2039	38.5	42.0	22.0	31.8	27.6	16.5	20.4	24.6
8. HADCM2 2050-2079	41.3	40.7	25.8	36.8	32.4	15.5	18.9	23.3
9. HADCM2 2080-2099	49.8	42.6	33.3	47.5	42.5	16.6	20.1	25.2
10. PCM 2010-2039	26.5	37.0	13.2	19.5	16.1	13.2	16.2	19.6
11. PCM 2050-2079	24.4	34.0	13.7	19.6	16.3	10.7	13.3	16.6
12. PCM 2080-2099	21.1	31.8	12.2	17.1	14.0	8.9	11.4	14.5
Historical (maf)	28.2	37.8	14.2	21.0	17.4	14.0	16.8	20.4

FURTHER COMPARATIVE CHANGES

Climate-induced changes in water supply availability are compared with estimated changes in urban and agriculture demands from 2020 to year 2100. Table 16 shows the comparative changes of overall water supply and urban and agriculture water demands.

Table 16. Comparative changes of water availability and demands (maf/yr).

Climate scenario	Availability change	Water demands changes 2020-2100		
		Overall	Urban	Agriculture
1. 1.5 T 0% P	-2.1	5.8	8.2	-2.7
2. 1.5 T 9% P	-0.1	5.8	8.2	-2.7
3. 3.0 T 0% P	-4.1	5.8	8.2	-2.7
4. 3.0 T 18% P	-0.8	5.8	8.2	-2.7
5. 5.0 T 0% P	-6.2	5.8	8.2	-2.7
6. 5.0 T 30% P	-1.6	5.8	8.2	-2.7
7. HADCM2 2010-2039	4.1	5.8	8.2	-2.7
8. HADCM2 2050-2079	2.7	5.8	8.2	-2.7
9. HADCM2 2080-2099	4.6	5.8	8.2	-2.7
10. PCM 2010-2039	-2.1	5.8	8.2	-2.7
11. PCM 2050-2079	-4.9	5.8	8.2	-2.7
12. PCM 2080-2099	-9.4	5.8	8.2	-2.7
Historical	0.0	0.0	0.0	0.0

FURTHER RESEARCH

The following research would help us to better understand and estimate climate change impacts on California's hydrology and water supplies:

1. Because current index basins are located on the north and middle Sierra Nevada, more index basins south of the delta, along the coast, and in the Central Valley floor would be useful.

2. Better ET representation in index basins and the Central Valley floor would be helpful.

3. Groundwater inflows and management can have an important role in moderating climate change effects and need further study.

4. Expansion and modification of existing storage facilities and their operation might be necessary to deal with changed timing pattern of rim inflows.

CONCLUSIONS

Streamflow changes of the six index basins and the effects of statewide temperature shifts and precipitation changes on CALVIN region hydrologies are mapped to construct a distributed hydrologic representation of different climate change scenarios for the CALVIN water management model. The hydrologic inflow results indicate that, under most climate change scenarios, California water quantity is expected to increase in the winter but decrease in the spring and summer. Among the GCM scenarios, HADCM2 scenarios result in increased water quantity and PCM scenarios indicate decreased water quantity. Regional analyses indicate the South is more sensitive to climate change and tends to get wetter faster than the North, but the South only accounts for a very small portion of water quantities compared to the North. Groundwater and local surface water accretion account for an important portion of total water quantity. Unlike increased winter rim inflows and local surface water accretions that would be lost if not stored in surface reservoirs, increased groundwater inflows would be stored in groundwater basins. For this reason, groundwater management could become more important for adaptation to climate change. In addition, expansion of existing storage reservoirs might be necessary to deal with changed seasonal timing of rim inflows. Demand management is another important option to consider. Water availability changes are different from those of overall water quantity changes because increased wet season surface inflows are likely to be largely lost in water availability analyses. On average, water availability decreases for all 12 climate change scenarios except the HADCM2 ones, even though the uniform temperature and precipitation incremental scenarios show increased overall water quantities. This analysis further stresses the importance of groundwater and reservoir management.

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Table A. Rim inflow changes for each CALVIN rim inflow location (%)

Scenario[a]	Trinity River Annual	Trinity River Oct.-Mar.	Trinity River Apr.-Sep.	Clear Creek Annual	Clear Creek Oct.-Mar.	Clear Creek Apr.-Sep.	Sacramento River Annual	Sacramento River Oct.-Mar.	Sacramento River Apr.-Sep.	Stony Creek Annual	Stony Creek Oct.-Mar.	Stony Creek Apr.-Sep.
1	-3.5	13.9	-20.3	-1.1	-0.4	-2.7	1.1	13.1	-17.8	-0.9	-0.3	-2.2
2	8.9	29.7	-11.1	9.3	10.7	5.8	14.3	29.0	-8.8	8.8	10.3	5.8
3	-6.3	25.9	-37.3	-1.3	-0.7	-2.8	2.6	24.7	-32.2	-1.3	-0.8	-2.2
4	18.0	60.7	-23.3	19.3	21.5	14.0	29.3	59.5	-18.3	18.1	20.4	13.4
5	-7.8	32.7	-47.0	-1.4	-0.8	-2.8	3.6	31.6	-40.4	-1.3	-0.8	-2.2
6	31.8	95.4	-29.7	32.9	36.1	25.2	49.0	94.4	-22.4	30.8	34.3	23.9
7	22.3	46.9	-1.5	18.8	20.5	14.7	28.3	46.0	0.4	17.3	18.9	14.2
8	26.7	69.4	-14.5	22.3	31.3	0.6	37.2	68.2	-11.7	20.6	30.3	1.0
9	44.7	112.9	-21.2	38.7	51.3	8.3	62.5	112.7	-16.4	36.7	50.6	8.7
10	-8.2	-9.5	-6.9	-6.4	-9.0	-0.1	-9.1	-10.5	-6.8	-6.1	-8.3	-1.8
11	-16.4	-5.4	-27.1	-11.0	-11.4	-9.9	-14.0	-6.7	-25.5	-7.8	-7.2	-9.1
12	-25.9	-13.3	-38.1	-15.9	-19.3	-7.5	-22.8	-15.2	-34.7	-14.2	-15.5	-11.4
Historical[b]	1217	598	619	263	186	77	5525	3379	2147	396	265	131

a. 12 climate change scenarios described in page 5
b. Historical average in taf.

Table A. Rim inflow changes for each CALVIN rim inflow location (%) (cont.)

Scenario[a]	Cottonwood Creek Annual	Cottonwood Creek Oct.-Mar.	Cottonwood Creek Apr.-Sep.	Lewiston Lake Inflow Annual	Lewiston Lake Inflow Oct.-Mar.	Lewiston Lake Inflow Apr.-Sep.	M & S Fork Yuba River Annual	M & S Fork Yuba River Oct.-Mar.	M & S Fork Yuba River Apr.-Sep.	Feather River Annual	Feather River Oct.-Mar.	Feather River Apr.-Sep.
1	-0.8	-0.2	-2.8	-1.2	23.4	-25.4	-1.3	16.0	-25.2	4.1	22.9	-18.6
2	9.6	10.7	5.9	12.8	41.1	-15.0	13.7	34.4	-14.7	17.8	40.4	-9.5
3	-1.1	-0.5	-2.9	-4.0	37.5	-44.7	-2.8	27.8	-44.9	5.0	36.9	-33.8
4	19.6	21.3	14.2	24.4	78.8	-29.2	27.6	68.7	-29.1	33.6	77.6	-19.9
5	-1.1	-0.6	-2.9	-6.5	42.6	-54.8	-4.4	32.5	-55.2	4.0	42.4	-42.5
6	33.2	35.7	25.5	39.8	116.9	-35.9	46.4	106.3	-36.1	52.1	115.4	-24.8
7	18.6	19.7	14.9	39.4	71.3	8.1	41.8	65.7	9.0	37.9	69.3	-0.2
8	23.8	31.0	1.0	47.2	102.3	-7.1	54.7	99.1	-6.5	49.5	100.7	-12.6
9	40.9	51.1	8.6	69.7	159.9	-19.0	84.0	158.5	-18.6	79.4	159.6	-17.9
10	-6.6	-8.9	0.4	-5.1	-4.9	-5.2	-5.5	-5.6	-5.2	-6.4	-6.0	-6.8
11	-9.8	-9.8	-9.8	-15.5	2.2	-32.9	-17.3	-6.0	-32.8	-10.9	1.5	-26.0
12	-15.3	-17.8	-7.2	-29.5	-10.8	-47.9	-32.5	-21.3	-47.9	-22.5	-11.5	-35.8
Historical[b]	554	421	133	46	23	23	426	247	179	3900	2137	1763

a. 12 climate change scenarios described in page 5.
b. Historical average in taf.

Table A. Rim inflow changes for each CALVIN rim inflow location (%) (cont.)

Scenario[a]	N. and M. Forks American River			South Fork American River			Cache Creek			Putah Creek		
	Annual	Oct.-Mar.	Apr.-Sep.	Annual	Oct.-Mar.	Apr.-Sep.	Annual	Oct.-Mar.	Apr.-Sep.	Annual	Oct.-Mar.	Apr.-Sep.
1	-1.6	15.0	-23.3	-0.5	21.9	-25.1	-1.2	-0.6	-2.5	-0.4	0.1	-3.2
2	13.4	33.6	-13.1	13.1	39.4	-15.5	8.7	10.1	5.8	10.2	11.0	5.6
3	-2.9	26.0	-40.8	-1.6	35.3	-41.8	-1.5	-1.0	-2.6	-0.6	-0.2	-3.3
4	27.5	67.6	-25.3	25.6	76.0	-29.3	18.2	20.3	13.8	20.5	21.6	13.9
5	-4.4	30.5	-50.1	-2.9	40.6	-50.4	-1.6	-1.1	-2.6	-0.7	-0.3	-3.3
6	46.7	105.5	-30.6	42.4	113.8	-35.5	31.2	34.3	24.7	34.4	35.8	25.3
7	41.1	65.9	8.6	33.9	68.6	-4.0	17.9	19.5	14.4	18.4	19.1	13.6
8	53.1	97.6	-5.3	44.4	98.4	-14.5	21.3	30.8	1.3	26.0	30.4	-0.6
9	80.3	153.4	-15.7	70.1	155.6	-23.1	36.5	49.5	8.8	45.4	51.7	6.4
10	-5.4	-5.9	-4.8	-7.2	-5.9	-8.6	-5.6	-8.0	-0.4	-7.6	-9.0	0.8
11	-18.5	-8.8	-31.2	-15.6	-1.2	-31.4	-8.8	-8.8	-8.9	-9.1	-8.9	-10.8
12	-33.3	-24.2	-45.2	-29.7	-14.4	-46.4	-14.4	-16.9	-9.1	-14.7	-16.6	-2.7
Historical[b]	1374	780	594	1311	684	627	499	339	160	372	320	52

a. 12 climate change scenarios described in page 5.
b. Historical average in taf.

Table A. Rim inflow changes for each CALVIN rim inflow location (%) (cont.)

Scenario[a]	North Fork Yuba River			Calaveras River			Mokelumne River			Cosumnes River		
	Annual	Oct.-Mar.	Apr.-Sep.	Annual	Oct.-Mar.	Apr.-Sep.	Annual	Oct.-Mar.	Apr.-Sep.	Annual	Oct.-Mar.	Apr.-Sep.
1	-0.1	24.0	-27.0	-1.1	-0.6	-3.0	6.0	20.1	-4.9	3.8	16.4	-21.9
2	14.0	41.5	-16.6	9.3	10.3	5.5	20.5	37.4	7.5	19.5	34.3	-10.6
3	-1.6	38.6	-46.3	-1.4	-0.9	-3.1	6.0	32.5	-14.3	5.2	28.2	-41.6
4	26.2	79.4	-33.1	19.2	20.7	13.6	35.9	72.0	8.2	37.1	68.0	-26.0
5	-3.4	44.1	-56.3	-1.5	-1.0	-3.1	-2.2	36.8	-32.2	4.4	32.6	-53.1
6	42.3	117.4	-41.4	32.8	34.9	24.7	44.3	107.0	-4.0	58.4	104.1	-34.9
7	35.8	70.9	-3.4	18.4	19.9	13.1	50.8	65.7	39.3	46.2	66.6	4.4
8	46.5	102.6	-16.0	24.1	30.7	-0.7	63.2	93.1	40.3	64.2	99.8	-8.3
9	72.9	162.3	-26.7	40.6	49.8	6.2	103.5	147.2	69.8	99.9	158.3	-19.2
10	-6.7	-5.0	-8.6	-6.5	-8.2	-0.2	-5.3	-5.3	-5.3	-5.9	-5.1	-7.6
11	-14.0	3.7	-33.6	-10.0	-9.9	-10.3	-11.9	-2.9	-18.8	-12.1	-2.9	-31.0
12	-28.1	-9.5	-48.9	-14.7	-17.7	-3.8	-26.7	-15.3	-35.4	-27.5	-19.2	-44.4
Historical[b]	1213	639	574	154	121	33	681	296	385	366	245	120

a. 12 climate change scenarios described in page 5.
b. Historical average in taf.

Table A. Rim inflow changes for each CALVIN rim inflow location (%) (cont.)

Scenario[a]	Deer Creek			Dry Creek			French Dry Creek			Greenhorn Creek and Bear River		
	Annual	Oct.-Mar.	Apr.-Sep.	Annual	Oct.-Mar.	Apr.-Sep.	Annual	Oct.-Mar.	Apr.-Sep.	Annual	Oct.-Mar.	Apr.-Sep.
1	-0.8	-0.3	-3.1	-1.0	-0.5	-3.5	-1.2	-0.6	-2.5	-1.0	15.8	-24.5
2	9.7	10.7	5.6	9.5	10.4	5.5	8.8	10.2	5.6	13.9	34.1	-14.3
3	-1.1	-0.6	-3.2	-1.3	-0.8	-3.6	-1.5	-1.0	-2.6	-1.2	27.4	-41.3
4	20.0	21.4	13.9	19.6	20.8	14.1	18.4	20.7	13.4	28.8	68.1	-26.3
5	-1.1	-0.6	-3.2	-1.4	-0.9	-3.6	-1.6	-1.1	-2.6	-2.1	32.0	-50.0
6	33.9	35.9	25.3	33.4	35.0	25.8	31.6	35.0	24.1	48.6	105.3	-30.9
7	18.9	20.1	13.9	18.7	19.7	13.6	18.2	20.2	13.6	41.2	66.0	6.5
8	25.0	31.1	-0.3	25.0	30.7	-1.8	21.8	31.5	0.1	54.5	98.5	-7.2
9	42.6	51.2	6.9	42.0	49.8	5.3	37.2	50.3	7.4	84.9	157.5	-16.9
10	-7.0	-8.9	1.1	-6.5	-8.2	1.4	-6.2	-8.5	-1.0	-5.1	-5.4	-4.6
11	-10.5	-10.5	-10.9	-10.1	-9.7	-12.5	-10.1	-10.1	-10.0	-16.3	-5.0	-32.0
12	-15.6	-18.5	-3.4	-14.3	-17.4	0.3	-15.3	-18.6	-8.0	-31.4	-21.0	-46.0
Historical[b]	68	55	13	81	67	14	133	92	41	418	244	174

a. 12 climate change scenarios described in page 5.
b. Historical average in taf.

Table A. Rim inflow changes for each CALVIN rim inflow location (%) (cont.)

Scenario[a]	Kelly Ridge			Stanislaus River			San Joaquin River			Merced River		
	Annual	Oct.-Mar.	Apr.-Sep.	Annual	Oct.-Mar.	Apr.-Sep.	Annual	Oct.-Mar.	Apr.-Sep.	Annual	Oct.-Mar.	Apr.-Sep.
1	-0.9	0.0	-1.7	6.5	21.5	-2.9	2.2	19.8	-7.1	8.2	23.9	0.6
2	8.8	12.2	5.9	20.8	38.7	9.6	16.0	36.7	5.1	22.5	41.1	13.5
3	-1.0	-0.1	-1.8	6.3	34.5	-11.4	-0.4	31.5	-17.2	8.2	38.1	-6.3
4	18.4	24.5	13.2	35.8	74.0	11.8	27.1	69.9	4.5	37.8	78.0	18.3
5	-1.0	-0.2	-1.8	-3.2	38.9	-29.7	-10.3	35.1	-34.3	-3.2	42.9	-25.5
6	31.6	41.5	23.2	42.2	109.1	0.1	30.4	102.7	-7.7	42.3	114.1	7.5
7	19.1	24.2	14.7	51.3	67.6	41.1	47.1	65.3	37.5	53.3	70.6	44.9
8	16.9	35.6	1.1	63.5	96.2	43.0	56.1	92.1	37.2	66.1	101.6	48.9
9	32.8	60.3	9.4	103.8	151.3	74.0	92.3	143.3	65.5	107.7	159.2	82.8
10	-8.0	-13.3	-3.5	-4.9	-4.9	-5.0	-5.3	-4.7	-5.6	-4.3	-4.3	-4.3
11	-13.8	-19.1	-9.3	-10.5	0.8	-17.6	-13.4	-0.7	-20.1	-8.7	5.4	-15.5
12	-21.3	-28.3	-15.4	-25.4	-12.1	-33.7	-29.0	-13.5	-37.2	-23.3	-7.7	-30.8
Historical[b]	126	58	68	1057	408	649	1681	580	1101	922	301	621

a. 12 climate change scenarios described in page 5.
b. Historical average in taf.

Table A. Rim inflow changes for each CALVIN rim inflow location (%) (cont.)

Scenario[a]	Fresno River			Chowchilla River			Clocal Inflow to New Don Pedro			Tuolumne River		
	Annual	Oct.-Mar.	Apr.-Sep.	Annual	Oct.-Mar.	Apr.-Sep.	Annual	Oct.-Mar.	Apr.-Sep.	Annual	Oct.-Mar.	Apr.-Sep.
1	-1.8	-1.2	-2.8	-1.5	-1.0	-3.3	-2.8	14.2	-22.7	-0.6	73.9	-16.2
2	8.1	9.4	5.9	8.6	9.5	5.6	10.4	29.7	-12.1	15.1	102.9	-3.4
3	-2.1	-1.6	-2.9	-1.9	-1.5	-3.4	-4.8	26.3	-41.2	-0.8	170.3	-36.8
4	17.5	19.4	14.2	18.2	19.4	14.1	21.2	60.5	-24.9	30.7	254.0	-16.3
5	-2.1	-1.7	-2.9	-2.0	-1.5	-3.4	-6.2	32.6	-51.6	-0.8	293.7	-62.7
6	30.4	33.1	25.6	31.4	33.1	25.8	36.3	93.9	-31.2	53.3	500.4	-40.8
7	17.9	19.7	14.8	18.0	19.3	13.9	30.4	46.9	11.2	45.9	145.2	25.0
8	20.1	30.7	1.4	23.1	30.4	-0.6	35.7	69.4	-3.8	60.7	259.4	18.9
9	33.1	46.8	8.8	37.8	47.4	6.5	54.3	113.2	-14.8	101.1	477.6	22.0
10	-3.9	-6.7	0.9	-4.9	-6.8	1.5	-6.9	-8.6	-4.9	-0.4	18.9	-4.5
11	-9.1	-9.1	-9.2	-8.9	-8.2	-11.2	-15.3	-1.6	-31.3	-19.1	17.9	-26.8
12	-13.0	-16.5	-6.8	-12.4	-15.6	-1.8	-26.1	-9.9	-45.0	-35.2	31.0	-49.1
Historical[b]	84	54	30	69	53	16	618	333	285	747	130	617

a. 12 climate change scenarios described in page 5.
b. Historical average in taf.

Table A. Rim inflow changes for each CALVIN rim inflow location (%) (cont.)

Scenario[a]	Cherry and Elnor			Santa Clara Valley Local			Kern River			Kaweah River		
	Annual	Oct.-Mar.	Apr.-Sep.	Annual	Oct.-Mar.	Apr.-Sep.	Annual	Oct.-Mar.	Apr.-Sep.	Annual	Oct.-Mar.	Apr.-Sep.
1	-1.5	16.9	-9.1	-0.1	0.3	-3.0	1.9	16.3	-3.9	-1.5	18.6	-10.8
2	12.6	34.1	3.7	11.4	12.2	5.9	15.6	32.8	8.8	12.7	35.7	2.1
3	-5.1	45.6	-26.2	-0.2	0.2	-3.0	3.6	44.9	-13.1	-3.3	50.5	-28.1
4	23.3	89.1	-4.0	22.9	24.2	14.5	31.7	85.6	10.1	25.2	93.6	-6.3
5	-7.8	99.3	-52.3	-0.2	0.2	-3.0	5.4	98.1	-31.8	-2.3	109.4	-53.7
6	39.2	196.9	-26.3	38.5	40.3	26.2	52.6	189.3	-2.3	45.9	207.3	-28.3
7	42.0	70.3	30.3	21.5	22.3	15.9	49.2	68.9	41.3	43.0	73.7	28.8
8	54.9	119.5	28.0	28.7	33.0	-0.8	63.3	114.8	42.7	56.2	122.4	25.8
9	89.9	219.8	35.9	50.5	56.7	7.7	113.9	214.8	73.4	95.9	232.6	33.1
10	-1.7	2.6	-3.4	-10.4	-11.9	-0.1	-3.3	1.3	-5.1	-1.9	2.2	-3.7
11	-17.0	-5.4	-21.8	-15.6	-16.1	-12.8	-14.3	-4.2	-18.3	-16.5	-1.9	-23.2
12	-32.5	-9.6	-42.0	-22.0	-24.4	-5.6	-27.4	-8.7	-34.9	-31.8	-6.3	-43.5
Historical[b]	436	128	308	126	110	16	684	196	488	416	131	285

a. 12 climate change scenarios described in page 5.
b. Historical average in taf.

Table A. Rim inflow changes for each CALVIN rim inflow location (%) (cont.)

Scenario[a]	Tule River			Kings River			Lower Owens Valley - Haiwee			Mono Basin		
	Annual	Oct.-Mar.	Apr.-Sep.	Annual	Oct.-Mar.	Apr.-Sep.	Annual	Oct.-Mar.	Apr.-Sep.	Annual	Oct.-Mar.	Apr.-Sep.
1	0.3	24.0	-26.2	0.6	17.6	-4.2	-0.6	2.6	-1.7	-2.1	62.8	-13.8
2	14.3	41.3	-15.6	14.2	34.2	8.5	12.7	17.1	11.3	12.8	91.0	-1.4
3	-1.4	38.2	-45.5	-0.6	48.1	-14.5	-1.9	10.1	-5.9	-2.9	145.5	-29.7
4	26.1	78.3	-31.8	26.7	89.4	8.7	24.9	44.2	18.5	26.5	225.5	-9.4
5	-3.7	43.1	-55.8	-3.8	104.5	-34.7	-4.4	32.9	-16.6	-3.7	254.6	-50.4
6	41.3	114.7	-40.2	39.8	198.1	-5.4	38.4	100.4	18.1	44.9	451.4	-28.5
7	36.6	71.2	-2.0	48.0	71.4	41.4	45.0	40.1	46.6	49.0	129.8	34.4
8	47.2	102.8	-14.6	59.2	118.6	42.2	56.2	67.0	52.6	61.0	236.4	29.3
9	72.1	159.7	-25.4	106.1	224.4	72.3	100.0	137.4	87.7	110.8	432.7	52.6
10	-6.3	-4.5	-8.4	-3.7	1.5	-5.2	-3.6	0.5	-4.9	-3.4	16.3	-6.9
11	-13.0	5.1	-33.2	-15.3	-3.0	-18.8	-16.3	-15.9	-16.4	-20.2	6.6	-25.0
12	-27.0	-8.0	-48.1	-29.6	-7.3	-36.0	-30.1	-26.3	-31.3	-36.2	15.5	-45.5
Historical[b]	132	69	62	1594	354	1240	292	72	220	119	18	101

a. 12 climate change scenarios described in page 5.
b. Historical average in taf.

Table A. Rim inflow changes for each CALVIN rim inflow location (%) (cont.)

Scenario[a]	Upper Owens		
	Annual	Oct.-Mar.	Apr.-Sep.
1	-6.5	11.9	-22.0
2	5.7	28.5	-13.5
3	-4.6	33.1	-36.2
4	20.7	73.9	-24.1
5	11.1	75.3	-42.9
6	60.2	164.5	-27.5
7	24.7	60.2	-5.2
8	38.7	104.4	-16.7
9	76.7	193.4	-21.5
10	-5.0	-1.3	-8.2
11	-20.6	-11.8	-28.0
12	-30.3	-18.2	-40.5
Historical[b]	143	66	78

a. 12 climate change scenarios described in page 5.
b. Historical average in taf.

Table B. Evaporation changes for each CALVIN surface reservoir (%)

Scenario[a]	Clair Engle Lake - Prosim			Whiskeytown Lake - Dwr_514			Shasta Lake - Dwr_514			Black Butte Lake		
	Annual	Oct.-Mar.	Apr.-Sep.	Annual	Oct.-Mar.	Apr.-Sep.	Annual	Oct.-Mar.	Apr.-Sep.	Annual	Oct.-Mar.	Apr.-Sep.
1	12.5	52.4	7.4	14.4	40.3	9.2	14.6	39.2	9.4	9.9	22.4	7.1
2	10.1	34.4	7.0	14.3	39.7	9.2	14.5	39.2	9.4	8.6	16.8	6.8
3	25.1	104.7	14.9	28.8	80.6	18.4	29.1	78.5	18.8	19.8	44.8	14.2
4	20.3	68.9	14.0	28.6	79.4	18.4	29.1	78.4	18.8	17.2	33.5	13.6
5	41.8	174.6	24.8	48.1	134.3	30.7	48.5	130.8	31.3	32.9	74.7	23.7
6	33.8	114.8	23.4	47.7	132.3	30.6	48.5	130.7	31.3	28.6	55.9	22.6
7	4.5	-4.4	5.6	12.9	35.3	8.4	13.3	36.0	8.6	5.3	4.0	5.6
8	11.4	18.8	10.4	22.6	62.3	14.6	23.3	62.7	15.0	11.1	15.4	10.2
9	11.1	-8.0	13.6	31.0	84.8	20.2	32.1	86.4	20.7	12.9	10.6	13.4
10	4.0	18.8	2.1	3.9	11.1	2.5	3.9	10.6	2.5	3.0	7.5	2.0
11	15.8	76.5	8.0	14.7	41.3	9.3	14.7	39.5	9.4	11.6	30.0	7.6
12	26.4	133.4	12.7	22.7	64.2	14.4	22.6	61.0	14.6	19.1	51.2	12.0
Historical[b]	29.36	3.33	26.03	10.81	1.81	9.00	80.07	13.87	66.20	2.18	0.39	1.79

a. 12 climate change scenarios described in page 5.
b. Historical average in taf.

Table B. Evaporation changes for each CALVIN surface reservoir (%) (cont.)

Scenario[a]	Lake Oroville - Dwr_514			Thermalito Forebay - Dwr_514			Folsom Lake - Dwr_514			Camp Far West Res. - Hec3_Bear		
	Annual	Oct.-Mar.	Apr.-Sep.	Annual	Oct.-Mar.	Apr.-Sep.	Annual	Oct.-Mar.	Apr.-Sep.	Annual	Oct.-Mar.	Apr.-Sep.
1	38.2	-178.2	18.3	39.0	-181.5	17.8	24.8	-141.2	13.3	12.0	39.0	6.8
2	41.2	-202.9	18.8	42.2	-206.4	18.2	22.7	-118.3	12.9	9.0	23.2	6.3
3	76.5	-356.5	36.7	78.1	-362.9	35.5	49.7	-282.4	26.6	23.9	78.0	13.6
4	82.5	-405.8	37.6	84.3	-412.7	36.4	45.5	-236.7	25.9	18.1	46.4	12.7
5	127.4	-594.1	61.1	130.2	-604.9	59.2	82.8	-470.6	44.3	39.8	130.1	22.6
6	137.5	-676.3	62.6	140.5	-687.8	60.6	75.8	-394.4	43.1	30.1	77.3	21.1
7	43.9	-236.0	18.2	45.0	-239.6	17.5	16.7	-62.7	11.2	2.4	-10.6	4.9
8	72.1	-374.5	31.0	73.8	-380.5	29.9	32.1	-143.0	20.0	8.6	5.0	9.2
9	105.1	-563.7	43.6	107.7	-572.3	42.1	40.4	-154.0	26.9	6.3	-23.1	11.9
10	9.6	-41.8	4.8	9.8	-42.6	4.7	7.3	-44.2	3.7	4.0	14.7	2.0
11	34.5	-146.5	17.8	35.1	-149.5	17.3	27.8	-172.4	13.9	15.9	60.3	7.4
12	50.6	-204.7	27.1	51.5	-209.1	26.4	44.6	-285.5	21.7	27.0	106.6	11.8
Historical[b]	28.01	-2.84	30.84	2.21	-0.24	2.45	21.01	-1.57	22.58	0.91	0.15	0.76

a. 12 climate change scenarios described in page 5.
b. Historical average in taf.

Table B. Evaporation changes for each CALVIN surface reservoir (%) (cont.)

Scenario[a]	Clear Lake and Indian Valley			Camanche Res. - Sanjasm_92			Ebmud Aggregate Local Storage			Englebright Lake - Hec3_Yuba		
	Annual	Oct.-Mar.	Apr.-Sep.	Annual	Oct.-Mar.	Apr.-Sep.	Annual	Oct.-Mar.	Apr.-Sep.	Annual	Oct.-Mar.	Apr.-Sep.
1	14.3	32.5	9.4	21.0	-125.8	10.7	5.1	-1.6	1.0	18.5	37.4	12.3
2	13.8	30.4	9.3	17.2	-83.7	10.0	-40.4	23.9	-1.2	20.5	44.6	12.6
3	28.5	65.0	18.7	42.1	-251.5	21.3	10.2	-3.2	2.0	36.9	74.9	24.6
4	27.5	60.8	18.5	34.3	-167.4	20.1	-80.9	47.8	-2.4	41.0	89.2	25.2
5	47.5	108.3	31.2	70.1	-419.2	35.5	16.9	-5.3	3.3	61.6	124.8	40.9
6	45.8	101.3	30.9	57.2	-279.0	33.4	-134.8	79.6	-3.9	68.3	148.6	42.0
7	11.6	23.6	8.4	8.0	7.8	7.9	-128.7	73.2	-5.5	22.9	55.4	12.3
8	21.0	44.3	14.7	19.6	-48.8	14.8	-156.8	89.8	-6.3	36.9	85.8	20.9
9	28.0	57.2	20.1	19.7	12.4	19.2	-302.7	172.2	-12.8	54.7	132.0	29.4
10	4.0	9.3	2.6	6.7	-45.0	3.0	13.2	-7.1	0.8	4.5	8.3	3.2
11	15.0	35.5	9.5	26.3	-182.3	11.6	65.5	-35.4	3.9	15.9	28.1	11.9
12	23.6	56.6	14.7	43.9	-317.5	18.4	140.3	-76.6	7.9	22.8	37.2	18.1
Historical[b]	57.07	12.11	44.95	4.30	-0.33	4.63	1.17	-1.83	3.00	3.94	0.97	2.97

a. 12 climate change scenarios described in page 5.

Table B. Evaporation changes for each CALVIN surface reservoir (%) (cont.)

Scenario[a]	Lake Berryesa			Los Vaqueros Res. - Ccwd			New Bullards Bar - Hec3_Yuba			New Hogan Lake - Sanjasm_92		
	Annual	Oct.-Mar.	Apr.-Sep.	Annual	Oct.-Mar.	Apr.-Sep.	Annual	Oct.-Mar.	Apr.-Sep.	Annual	Oct.-Mar.	Apr.-Sep.
1	13.6	31.8	8.7	1.0	2.2	0.7	12.2	25.8	8.6	5.0	9.2	3.6
2	13.2	30.1	8.7	-4.6	-19.7	-0.2	11.6	23.3	8.5	2.1	-0.2	2.9
3	27.3	63.7	17.4	2.0	4.4	1.3	24.4	51.5	17.2	10.1	18.4	7.2
4	26.4	60.1	17.3	-9.2	-39.5	-0.4	23.1	46.6	16.9	4.2	-0.4	5.8
5	45.5	106.1	29.1	3.4	7.4	2.2	40.6	85.8	28.6	16.8	30.7	12.0
6	44.1	100.2	28.9	-15.4	-65.8	-0.7	38.5	77.6	28.2	7.0	-0.7	9.6
7	11.3	24.1	7.9	-15.6	-62.3	-2.0	9.4	16.4	7.5	-4.0	-19.1	1.2
8	20.3	44.5	13.8	-18.8	-76.0	-2.1	17.2	32.3	13.3	-2.6	-19.4	3.1
9	27.2	58.1	18.9	-36.6	-146.5	-4.6	22.6	39.8	18.0	-9.2	-44.6	3.0
10	3.8	9.1	2.4	1.7	6.3	0.4	3.5	7.6	2.4	2.1	4.9	1.2
11	14.3	34.4	8.8	8.5	31.4	1.8	13.1	29.2	8.8	9.0	21.8	4.6
12	22.4	54.5	13.7	18.0	67.3	3.6	20.7	47.1	13.7	16.4	41.7	7.7
Historical[b]	46.14	9.82	36.32	4.76	1.07	3.68	18.23	3.81	14.42	8.22	2.11	6.12

a. 12 climate change scenarios described in page 5.

Table B. Evaporation changes for each CALVIN surface reservoir (%) (cont.)

Scenario[a]	Pardee Res. – Sanjasm_92			New Melones Res. - Dwr_514			Swp San Luis Res. - Dwr_514			Del Valle Reservoir - Dwr_514		
	Annual	Oct.-Mar.	Apr.-Sep.	Annual	Oct.-Mar.	Apr.-Sep.	Annual	Oct.-Mar.	Apr.-Sep.	Annual	Oct.-Mar.	Apr.-Sep.
1	21.9	-152.9	10.7	11.6	27.0	7.5	20.5	50.0	11.9	8.1	37.3	4.8
2	17.7	-102.2	10.0	10.1	20.9	7.2	20.5	50.2	11.9	2.3	-10.6	3.8
3	43.8	-305.8	21.3	23.2	54.0	15.0	40.9	100.0	23.7	16.3	74.6	9.5
4	35.5	-204.5	20.0	20.1	41.7	14.4	41.1	100.5	23.7	4.6	-21.1	7.6
5	73.0	-509.6	35.5	38.6	90.1	25.0	68.2	166.6	39.5	27.1	124.3	15.8
6	59.1	-340.8	33.4	33.5	69.5	24.0	68.5	167.4	39.6	7.7	-35.2	12.6
7	7.9	8.0	7.9	6.2	6.7	6.0	19.0	46.6	10.9	-9.6	-106.0	1.5
8	19.9	-61.0	14.7	13.0	20.9	10.9	33.0	80.8	19.0	-8.1	-113.7	4.1
9	19.6	11.8	19.1	15.1	17.1	14.6	45.6	112.0	26.3	-22.3	-247.6	3.9
10	7.0	-54.5	3.1	3.5	8.9	2.1	5.5	13.5	3.2	3.7	22.5	1.5
11	27.5	-221.0	11.6	13.7	35.4	7.9	20.5	50.0	11.9	15.9	101.0	6.1
12	46.1	-384.5	18.4	22.4	59.9	12.5	31.6	76.8	18.4	29.6	197.0	10.2
Historical[b]	3.90	-0.27	4.16	44.64	9.34	35.30	91.98	20.78	71.20	2.07	0.22	1.86

a. 12 climate change scenarios described in page 5.
b. Historical average in taf.

Table B. Evaporation changes for each CALVIN surface reservoir (%) (cont.)

Scenario[a]	Millerton Lake - Dwr_514			Lake Mcclure - Dwr_514			Los Banos Grandes Res. - Dwr_514			Hensley Lake - Dwr_514		
	Annual	Oct.-Mar.	Apr.-Sep.	Annual	Oct.-Mar.	Apr.-Sep.	Annual	Oct.-Mar.	Apr.-Sep.	Annual	Oct.-Mar.	Apr.-Sep.
1	13.7	35.4	8.7	12.8	33.2	8.5	11.1	27.1	8.6	12.2	31.2	8.3
2	13.1	32.7	8.6	12.1	29.8	8.4	9.0	15.9	7.9	11.4	27.5	8.1
3	27.4	70.7	17.4	25.6	66.3	17.1	22.1	54.1	17.3	24.3	62.4	16.7
4	26.2	65.5	17.1	24.2	59.6	16.8	18.0	31.7	15.9	22.7	54.9	16.3
5	45.7	117.9	29.0	42.7	110.6	28.5	36.8	90.2	28.8	40.5	104.0	27.8
6	43.7	109.2	28.5	40.4	99.4	28.0	29.9	52.9	26.5	37.8	91.5	27.1
7	10.8	24.8	7.6	9.7	20.6	7.5	4.1	-8.0	5.9	8.8	17.7	7.1
8	19.8	47.1	13.4	18.0	40.9	13.2	10.2	2.7	11.3	16.5	36.3	12.6
9	26.1	60.0	18.3	23.5	50.1	17.9	10.1	-17.5	14.3	21.3	43.0	17.0
10	3.9	10.3	2.4	3.6	9.9	2.3	3.5	10.2	2.5	3.5	9.4	2.3
11	14.6	39.1	8.9	13.8	37.8	8.8	13.9	42.1	9.6	13.3	36.4	8.7
12	23.0	62.5	13.8	21.9	61.2	13.7	23.2	74.6	15.4	21.2	59.3	13.5
Historical[b]	18.03	3.39	14.65	33.90	5.85	28.05	0.00	0.00	0.00	2.62	0.44	2.19

a. 12 climate change scenarios described in page 5.
b. Historical average in taf.

Table B. Evaporation changes for each CALVIN surface reservoir (%) (cont.)

Scenario[a]	Eastman Lake - Dwr_514			Don Pedro Res. - Dwr_514			Sr-Asf			Sr-Hhr		
	Annual	Oct.-Mar.	Apr.-Sep.	Annual	Oct.-Mar.	Apr.-Sep.	Annual	Oct.-Mar.	Apr.-Sep.	Annual	Oct.-Mar.	Apr.-Sep.
1	12.8	32.0	8.4	11.5	28.2	7.6	1.0	2.2	0.7	11.8	28.2	7.6
2	11.9	28.1	8.2	10.1	22.1	7.3	-4.7	-20.1	-0.3	10.4	22.2	7.3
3	25.5	64.0	16.8	23.0	56.4	15.1	2.0	4.5	1.3	23.6	56.4	15.2
4	23.7	56.2	16.4	20.2	44.3	14.6	-9.3	-40.2	-0.5	20.7	44.3	14.7
5	42.6	106.7	28.0	38.3	94.0	25.2	3.3	7.4	2.2	39.4	94.0	25.4
6	39.6	93.7	27.3	33.7	73.8	24.3	-15.5	-67.0	-0.9	34.6	73.9	24.5
7	9.1	18.0	7.1	6.5	8.1	6.2	-15.7	-63.4	-2.1	6.6	8.2	6.2
8	17.2	37.1	12.6	13.4	23.1	11.2	-18.9	-77.4	-2.3	13.7	23.2	11.2
9	22.0	43.8	17.0	15.9	20.4	14.9	-36.8	-149.1	-4.9	16.1	20.6	14.9
10	3.7	9.7	2.3	3.5	9.2	2.1	1.7	6.4	0.4	3.6	9.2	2.1
11	14.0	37.4	8.8	13.4	36.4	8.0	8.5	31.9	1.9	13.8	36.4	8.0
12	22.4	61.0	13.7	21.8	61.4	12.5	18.0	68.4	3.7	22.5	61.3	12.6
Historical[b]	2.94	0.54	2.39	57.41	10.89	46.52	7.46	1.65	5.81	13.16	2.68	10.48

a. 12 climate change scenarios described in page 5.
b. Historical average in taf.

Table B. Evaporation changes for each CALVIN surface reservoir (%) (cont.)

Scenario[a]	SR LL – LE			SR - SCV			Tulloch Res. - Sanjasm_92			Lake Isabella		
	Annual	Oct.-Mar.	Apr.-Sep.	Annual	Oct.-Mar.	Apr.-Sep.	Annual	Oct.-Mar.	Apr.-Sep.	Annual	Oct.-Mar.	Apr.-Sep.
1	11.2	28.0	7.5	1.0	2.2	0.7	12.9	29.5	8.3	10.9	24.6	7.8
2	9.9	22.1	7.3	-5.1	-20.7	-0.4	12.0	25.9	8.1	10.8	23.8	7.8
3	22.4	56.1	15.0	2.0	4.4	1.3	25.8	59.0	16.6	21.9	49.2	15.6
4	19.8	44.2	14.5	-10.2	-41.3	-0.9	24.0	51.9	16.3	21.5	47.6	15.5
5	37.3	93.5	25.0	3.4	7.4	2.2	43.0	98.3	27.7	36.5	82.0	26.1
6	33.0	73.7	24.2	-17.0	-68.9	-1.5	40.0	86.5	27.1	35.9	79.3	25.9
7	6.6	8.4	6.2	-17.0	-65.0	-2.7	9.2	16.7	7.2	9.5	20.2	7.0
8	13.3	23.4	11.1	-20.5	-79.4	-3.0	17.4	34.4	12.7	16.8	36.4	12.3
9	16.0	21.0	14.9	-39.9	-152.9	-6.2	22.3	40.7	17.2	22.9	48.8	16.9
10	3.4	9.1	2.1	1.9	6.5	0.5	3.7	8.9	2.3	3.0	6.9	2.1
11	12.9	36.1	7.9	9.2	32.6	2.2	14.2	34.4	8.6	11.3	25.8	7.9
12	21.0	60.8	12.4	19.4	70.0	4.3	22.6	56.0	13.3	17.5	40.5	12.3
Historical[b]	13.63	2.43	11.20	7.04	1.62	5.42	6.87	1.49	5.38	20.59	3.84	16.75

a. 12 climate change scenarios described in page 5.
b. Historical average in taf.

Table B. Evaporation changes for each CALVIN surface reservoir (%) (cont.)

Scenario[a]	Lake Kaweah			Lake Success			Pine Flat Res.			Silverwood Lake - Dwr_514		
	Annual	Oct.-Mar.	Apr.-Sep.	Annual	Oct.-Mar.	Apr.-Sep.	Annual	Oct.-Mar.	Apr.-Sep.	Annual	Oct.-Mar.	Apr.-Sep.
1	10.3	29.1	8.8	9.2	23.3	7.6	11.2	28.6	7.4	11.6	33.4	7.1
2	10.2	28.2	8.8	8.7	20.4	7.4	10.1	23.7	7.1	8.8	19.6	6.6
3	20.7	58.1	17.6	18.4	46.6	15.3	22.3	57.2	14.7	23.2	66.9	14.3
4	20.4	56.4	17.5	17.5	40.7	14.9	20.1	47.4	14.2	17.6	39.2	13.2
5	34.4	96.9	29.4	30.7	77.6	25.5	37.2	95.3	24.5	38.7	111.5	23.8
6	34.0	94.0	29.2	29.1	67.9	24.8	33.6	78.9	23.7	29.3	65.4	21.9
7	9.1	24.2	7.9	7.0	12.9	6.4	7.1	11.9	6.0	2.4	-9.8	4.9
8	16.1	43.4	13.9	13.0	26.7	11.5	13.9	28.0	10.9	8.4	3.4	9.4
9	22.0	58.2	19.1	17.0	31.3	15.4	17.2	29.3	14.5	6.2	-21.5	11.9
10	2.8	8.1	2.4	2.6	7.1	2.1	3.3	9.0	2.1	3.9	12.6	2.1
11	10.5	30.4	8.9	9.9	27.3	8.0	12.6	35.3	7.7	15.4	52.0	7.9
12	16.4	47.6	13.9	15.7	44.6	12.5	20.4	58.6	12.1	26.2	92.1	12.7
Historical[b]	1.14	0.09	1.06	4.91	0.49	4.42	13.02	2.33	10.69	1.37	0.23	1.13

a. 12 climate change scenarios described in page 5.
b. Historical average in taf.

Table B. Evaporation changes for each CALVIN surface reservoir (%) (cont.)

Scenario[a]	Lake Perris - DWR_514			Pyramid Lake - DWR_514			Castaic Lake - DWR_514			Eastside		
	Annual	Oct.-Mar.	Apr.-Sep.	Annual	Oct.-Mar.	Apr.-Sep.	Annual	Oct.-Mar.	Apr.-Sep.	Annual	Oct.-Mar.	Apr.-Sep.
1	19.0	73.7	11.2	12.4	49.4	7.0	15.2	51.3	8.9	21.1	77.8	12.3
2	17.6	63.7	10.9	8.5	22.4	6.4	12.7	36.9	8.5	19.2	65.6	11.9
3	38.0	147.4	22.3	24.8	98.8	14.0	30.4	102.6	17.9	42.3	155.6	24.6
4	35.1	127.5	21.9	16.9	44.8	12.9	25.5	73.7	17.1	38.3	131.3	23.8
5	63.3	245.6	37.2	41.4	164.6	23.4	50.7	171.0	29.8	70.5	259.3	40.9
6	58.5	212.4	36.5	28.2	74.7	21.4	42.5	122.8	28.5	63.9	218.8	39.6
7	13.2	38.5	9.6	-0.2	-33.7	4.7	6.7	4.8	7.1	13.6	35.9	10.1
8	25.2	81.8	17.1	5.5	-18.8	9.1	15.4	29.7	12.9	26.6	80.5	18.2
9	32.0	94.0	23.1	0.2	-77.1	11.4	16.6	13.6	17.1	33.0	88.0	24.4
10	5.5	22.5	3.1	4.4	20.4	2.1	4.8	17.6	2.5	6.2	24.2	3.4
11	21.0	87.3	11.5	17.7	85.5	7.8	18.6	70.8	9.5	23.9	94.3	12.9
12	33.6	143.3	17.9	30.7	155.1	12.6	30.8	121.6	15.0	38.5	156.0	20.2
Historical[b]	8.28	1.04	7.24	5.74	0.73	5.01	7.70	1.14	6.56	13.64	1.84	11.80

a. 12 climate change scenarios described in page 5.
b. Historical average in taf.

Table B. Evaporation changes for each CALVIN surface reservoir (%) (cont.)

Scenario[a]	Grant Lake			Laa Storage			Lake Crowley			Lk Mathews		
	Annual	Oct.-Mar.	Apr.-Sep.	Annual	Oct.-Mar.	Apr.-Sep.	Annual	Oct.-Mar.	Apr.-Sep.	Annual	Oct.-Mar.	Apr.-Sep.
1	11.5	28.3	8.5	7.7	15.9	5.3	9.3	20.1	6.4	25.1	109.0	12.3
2	12.5	31.7	9.0	7.1	14.0	5.0	9.4	20.7	6.4	22.4	91.3	11.9
3	23.1	56.6	16.9	15.4	31.9	10.5	18.5	40.2	12.8	50.3	218.1	24.6
4	25.1	63.3	18.0	14.2	28.0	10.0	18.9	41.3	12.9	44.9	182.6	23.8
5	38.5	94.3	28.2	25.7	53.1	17.5	30.9	67.0	21.3	83.8	363.5	41.0
6	41.8	105.5	30.0	23.6	46.7	16.7	31.4	68.9	21.5	74.8	304.3	39.6
7	13.5	35.8	9.4	5.3	9.0	4.1	9.0	20.1	6.0	15.2	48.1	10.1
8	22.0	57.4	15.5	10.1	18.5	7.6	15.4	34.2	10.4	30.4	110.1	18.2
9	32.3	85.7	22.4	12.7	21.9	10.0	21.6	48.2	14.5	36.9	118.2	24.4
10	2.9	6.8	2.1	2.2	4.8	1.5	2.5	5.3	1.7	7.5	34.1	3.4
11	10.3	24.0	7.8	8.6	18.6	5.6	9.1	19.5	6.3	28.9	133.2	12.9
12	15.1	34.1	11.5	13.8	30.3	8.8	13.9	29.6	9.7	46.9	220.8	20.2
Historical[b]	3.81	0.59	3.21	2.94	0.67	2.26	6.09	1.28	4.81	8.51	1.13	7.38

a. 12 climate change scenarios described in page 5.
b. Historical average in taf.

Table B. Evaporation changes for each CALVIN surface reservoir (%) (cont.)

Scenario[a]	Lk Skinner			Mono Lake			Salton Sea		
	Annual	Oct.-Mar.	Apr.-Sep.	Annual	Oct.-Mar.	Apr.-Sep.	Annual	Oct.-Mar.	Apr.-Sep.
1	22.1	85.4	12.3	14.0	29.4	9.2	9.7	17.4	6.7
2	20.0	71.9	11.9	15.4	33.2	9.8	8.8	15.3	6.3
3	44.2	170.8	24.6	28.1	58.8	18.4	19.4	34.7	13.5
4	39.9	143.8	23.8	30.7	66.3	19.6	17.6	30.5	12.6
5	73.7	284.7	41.0	46.8	98.0	30.7	32.3	57.9	22.4
6	66.6	239.7	39.7	51.2	110.5	32.7	29.3	50.8	21.0
7	14.0	38.9	10.1	16.8	38.0	10.2	6.3	9.7	4.9
8	27.6	87.7	18.2	27.3	60.6	16.9	12.2	20.1	9.2
9	34.0	95.4	24.4	40.2	90.8	24.4	15.2	23.7	11.9
10	6.5	26.6	3.4	3.5	7.0	2.3	2.9	5.3	1.9
11	25.1	103.8	12.9	12.3	24.6	8.5	10.9	20.3	7.3
12	40.6	171.8	20.2	17.9	34.7	12.6	17.6	33.1	11.7
Historical[b]	5.66	0.76	4.90	68.98	16.45	52.53	828.01	229.72	598.29

a. 12 climate change scenarios described in page 5.
b. Historical average in taf.

Table C. Changes for each CALVIN groundwater basin inflows (%)

Scenario[a]	Source_GW-1			Source_GW-2			Source_GW-3			Source_GW-4		
	Annual	Oct.-Mar.	Apr.-Sep.	Annual	Oct.-Mar.	Apr.-Sep.	Annual	Oct.-Mar.	Apr.-Sep.	Annual	Oct.-Mar.	Apr.-Sep.
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	674.0	19.4	-3.2	7.5	8.8	3.8	123.7	22.2	-3.2	1.9	3.2	0.5
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	1347.9	38.9	-6.4	15.0	17.6	7.5	247.4	44.5	-6.4	3.8	6.5	0.9
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	2246.5	64.8	-10.7	25.0	29.3	12.6	412.3	74.1	-10.7	6.4	10.8	1.5
7	1643.1	45.6	-9.6	18.1	20.9	9.9	306.4	54.2	-9.0	5.5	8.5	2.1
8	2104.5	68.2	-2.2	23.5	31.1	1.2	413.9	80.9	-2.6	7.2	12.8	1.0
9	3543.1	113.4	-5.3	41.0	53.2	5.3	725.2	140.8	-5.8	11.7	21.2	1.1
10	-490.1	-16.8	-0.5	-6.9	-8.7	-1.6	-119.4	-23.3	0.8	-1.4	-3.0	0.4
11	-813.9	-23.2	4.2	-11.3	-11.8	-9.6	-209.6	-35.6	8.1	-2.7	-4.5	-0.7
12	-1420.2	-45.4	2.2	-18.8	-22.9	-6.9	-332.4	-62.0	5.9	-4.5	-8.7	0.1
Historical[b]	1.9	55.4	-53.5	402.7	300.1	102.6	11.7	58.3	-46.6	263.1	138.5	124.6

a. 12 climate change scenarios described in page 5.
b. Historical average in taf.

Table C. Changes for each CALVIN groundwater basin inflows (%) (cont.)

Scenario[a]	Source_GW-5			Source_GW-6			Source_GW-7			Source_GW-8		
	Annual	Oct.-Mar.	Apr.-Sep.	Annual	Oct.-Mar.	Apr.-Sep.	Annual	Oct.-Mar.	Apr.-Sep.	Annual	Oct.-Mar.	Apr.-Sep.
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	14.9	12.5	-17.0	2.4	3.7	1.2	2.4	3.9	0.4	0.9	1.5	0.3
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	29.7	25.1	-33.9	4.8	7.5	2.4	4.7	7.7	0.9	1.8	3.1	0.5
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	49.5	41.8	-56.5	8.1	12.4	3.9	7.8	12.9	1.5	3.1	5.1	0.9
7	39.1	30.5	-78.8	5.6	11.3	0.1	6.3	9.6	2.2	3.0	4.4	1.5
8	52.8	46.7	-31.2	7.1	14.7	-0.2	8.7	14.7	1.1	3.8	6.5	1.0
9	90.3	81.1	-35.9	13.0	23.6	2.8	15.1	26.2	1.0	5.8	10.5	0.9
10	-10.4	-10.8	-15.9	-1.6	-2.6	-0.6	-1.6	-3.2	0.4	-0.5	-1.2	0.3
11	-17.9	-14.8	24.5	-4.3	-6.1	-2.5	-2.8	-4.5	-0.8	-1.3	-2.1	-0.4
12	-32.1	-30.6	-11.1	-6.7	-9.6	-3.9	-5.3	-9.5	0.1	-2.2	-4.1	-0.1
Historical[b]	144.9	156.3	-11.4	365.7	178.6	187.1	278.0	155.2	122.9	747.4	386.6	360.8

a. 12 climate change scenarios described in page 5.
b. Historical average in taf.

Table C. Changes for each CALVIN groundwater basin inflows (%) (cont.)

Scenario[a]	Source_GW-9			Source_GW-10			Source_GW-11			Source_GW-12		
	Annual	Oct.-Mar.	Apr.-Sep.	Annual	Oct.-Mar.	Apr.-Sep.	Annual	Oct.-Mar.	Apr.-Sep.	Annual	Oct.-Mar.	Apr.-Sep.
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	149.7	23.1	-3.3	1.9	3.5	0.5	-14.5	-79.3	-2.1	2.3	4.0	0.7
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	299.3	46.2	-6.6	3.8	7.1	1.0	-29.0	-158.6	-4.3	4.7	8.0	1.5
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	498.9	77.1	-11.0	6.3	11.8	1.6	-48.3	-264.3	-7.1	7.8	13.3	2.4
7	468.5	66.6	-17.3	6.7	10.8	3.2	-47.0	-226.0	-12.9	8.2	11.7	4.8
8	626.5	99.9	-10.1	8.4	16.0	2.1	-62.0	-347.8	-7.6	10.2	17.5	3.1
9	1007.3	166.6	-9.0	14.0	28.3	2.0	-97.7	-576.1	-6.6	15.8	28.9	2.8
10	-104.2	-20.9	-3.5	-1.2	-3.2	0.4	8.7	65.5	-2.2	-1.0	-2.9	0.8
11	-222.7	-33.4	6.1	-2.8	-5.0	-1.0	21.4	110.2	4.5	-3.5	-5.7	-1.3
12	-376.5	-64.3	0.9	-4.8	-9.8	-0.6	35.6	216.0	1.2	-5.6	-10.8	-0.6
Historical[b]	13.2	76.7	-63.4	299.2	136.9	162.3	-157.3	-25.1	-132.2	156.9	77.8	79.1

a. 12 climate change scenarios described in page 5.
b. Historical average in taf.

Table C. Changes for each CALVIN groundwater basin inflows (%) (cont.)

Scenario[a]	Source_GW-13			Source_GW-14			Source_GW-15			Source_GW-16		
	Annual	Oct.-Mar.	Apr.-Sep.	Annual	Oct.-Mar.	Apr.-Sep.	Annual	Oct.-Mar.	Apr.-Sep.	Annual	Oct.-Mar.	Apr.-Sep.
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	1.1	2.1	0.3	3.2	9.5	0.6	0.5	1.0	0.1	0.7	1.4	0.2
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	2.2	4.2	0.6	6.5	19.0	1.1	0.9	2.1	0.2	1.3	2.8	0.3
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	3.7	7.0	1.0	10.8	31.7	1.8	1.6	3.4	0.3	2.2	4.7	0.6
7	4.1	6.3	2.4	12.8	33.3	4.0	1.8	3.4	0.8	2.5	4.2	1.3
8	5.0	9.4	1.5	14.5	43.0	2.3	2.1	4.6	0.4	2.9	6.1	0.8
9	7.9	16.2	1.5	28.5	88.5	2.8	4.1	9.3	0.6	5.0	11.3	1.0
10	-0.4	-1.4	0.4	-2.7	-9.2	0.1	-0.4	-1.0	0.0	-0.3	-1.1	0.2
11	-1.6	-3.1	-0.5	-4.4	-11.4	-1.4	-0.7	-1.4	-0.2	-0.9	-1.9	-0.3
12	-2.7	-5.7	-0.4	-8.4	-24.8	-1.3	-1.2	-2.7	-0.2	-1.6	-3.6	-0.3
Historical[b]	872.1	380.7	491.4	314.6	94.3	220.2	1167.3	469.6	697.7	278.1	109.1	169.0

a. 12 climate change scenarios described in page 5.
b. Historical average in taf.

Table C. Changes for each CALVIN groundwater basin inflows (%) (cont.)

Scenario[a]	Source_G-17			Source_GW-18			Source_GW-19			Source_GW-20		
	Annual	Oct.-Mar.	Apr.-Sep.	Annual	Oct.-Mar.	Apr.-Sep.	Annual	Oct.-Mar.	Apr.-Sep.	Annual	Oct.-Mar.	Apr.-Sep.
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	1.6	3.6	0.4	2.8	4.7	0.8	5.3	5.4	4.9	2.2	3.6	0.8
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	3.2	7.2	0.9	5.7	9.3	1.6	10.6	10.8	9.8	4.4	7.3	1.6
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	5.4	12.0	1.5	9.5	15.6	2.7	17.7	18.0	16.4	7.4	12.1	2.6
7	6.2	10.9	3.4	11.1	15.7	5.9	23.2	20.2	37.8	9.6	13.0	6.2
8	7.1	15.8	2.0	12.4	20.9	2.9	24.3	25.1	20.5	10.1	16.9	3.4
9	12.4	29.1	2.6	25.1	43.5	4.7	50.6	54.1	33.2	20.8	35.8	5.9
10	-0.6	-2.3	0.4	-2.0	-4.0	0.1	-5.6	-6.5	-1.3	-1.7	-3.5	0.0
11	-2.3	-4.9	-0.8	-4.2	-6.2	-2.0	-8.6	-7.7	-12.8	-3.5	-5.3	-1.6
12	-4.0	-8.9	-1.0	-7.2	-11.4	-2.4	-15.0	-14.4	-17.8	-6.1	-9.1	-3.1
Historical[b]	358.7	133.4	225.4	484.8	255.7	229.1	166.9	138.5	28.4	219.4	109.2	110.2

a. 12 climate change scenarios described in page 5.
b. Historical average in taf.

Table C. Changes for each CALVIN groundwater basin inflows (%) (cont.)

Scenario[a]	Source_GW-21		
	Annual	Oct.-Mar.	Apr.-Sep.
1	0.0	0.0	0.0
2	2.9	4.4	1.2
3	0.0	0.0	0.0
4	5.9	8.8	2.3
5	0.0	0.0	0.0
6	9.8	14.6	3.8
7	12.4	15.7	8.3
8	13.3	20.5	4.2
9	28.5	45.0	8.0
10	-3.2	-5.2	-0.6
11	-5.3	-7.2	-2.9
12	-8.7	-11.6	-5.0
Historical[b]	390.4	216.8	173.6

a. 12 climate change scenarios described in page 5.
b. Historical average in taf.